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FM 6-2

DEPARTMENT OF THE ARMY FIELD MANUAL

55

ARTILLERY SURVEY



● HEADQUARTERS, DEPARTMENT OF THE ARMY
AUGUST 1961



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FIELD MANUAL }
No. 6-2

HEADQUARTERS,
DEPARTMENT OF THE ARMY
WASHINGTON 25, D.C., 7 August 1961

ARTILLERY SURVEY

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PART ONE

GENERAL

CHAPTER 1

INTRODUCTION

1. Purpose

a. This manual is a guide for commanders, survey officers, and personnel engaged in the conduct of artillery surveys. It provides a basis for instruction, guidance, and reference in surveying principles and procedures, and in the care and operation of surveying instruments. Procedures covering all situations cannot be prescribed; therefore, the instructions contained herein should be used as a guide in developing the application of suitable techniques. The material presented herein is applicable without modification to both nuclear and nonnuclear warfare.

b. Users of this manual are encouraged to submit recommended changes or comments to improve the manual. Comments should be keyed to the specific page, paragraph, and line of the text in which the change is recommended. Reasons should be provided for each comment to insure understanding and complete evaluation. Comments should be forwarded direct to the Commandant, U.S. Army Artillery and Missile School, Fort Sill, Oklahoma.

2. Scope

This manual expounds the survey personnel and equipment available to artillery units, the measurement of angles and distances, and the determination of relative locations on a rectangular grid system.

3. References

Publications used as references for the manual and those offering further technical information are listed in appendix I.

4. Definitions

Technical terms not included in AR 320-5 are defined the first time they are used in this manual.

5. Fundamental Operations of Survey

Survey results are obtained from the following:

a. *Planning.* A thorough plan which gives full consideration to the factors affecting survey and conforms to basic essentials contributes to a successful accomplishment of the survey.

b. *Fieldwork.* Survey fieldwork consists of—
(1) Measuring distances.
(2) Measuring horizontal and/or vertical angles.

(3) Recording all pertinent data.

c. *Computations.* The computations are performed simultaneously with the fieldwork. The known data and the fieldwork data are combined to produce the location and/or height of a point and/or the direction of a certain line.

6. Accuracy

Three minimum orders of accuracy are prescribed for artillery surveys: artillery fourth-order survey, 1:3,000; artillery fifth-order survey, 1:1,000; and artillery 1:500; e.g., an accuracy of 1:3,000 means that for each 3,000 units of distance surveyed, the error cannot exceed 1 unit. The order or accuracy required depends on the intended use of the survey data.

7. Survey Specifications and Techniques

Specifications and techniques required to achieve each artillery order of survey accuracy set forth in paragraph 6 are listed in appendix II.

CHAPTER 2

ARTILLERY SURVEY PURPOSE AND RESPONSIBILITIES

8. Purpose of Artillery Survey

Artillery survey operations provide a common grid which will permit the massing of fires, delivery of surprise observed fires, delivery of effective unobserved fires, and transmission of target data from one unit to another. The establishment of a common grid is a command responsibility.

9. Responsibilities of the Corps of Engineers

a. The survey responsibilities of the Corps of Engineers are described in AR 117-5 and TM 5-231. In regard to artillery survey, engineer responsibilities include—

- (1) The supply of maps.
- (2) The supply of trig lists and other survey control data.
- (3) Extension of ground control as described in *b* and *c* below.

b. When existing survey control is not available, the normal procedure is for the survey company of the engineer base topographic battalion to extend control to the rear boundary of army areas; the survey platoon of the engineer topographic battalion (army) to extend control to the rear boundaries of subordinate corps; and the survey platoon of the engineer topographic company to extend control as directed by the corps commander.

c. The survey element organic to the engineer combat battalion, missile command (medium), has the responsibility of providing survey control point throughout the width of the missile command area for use by the survey platoons of the target acquisition battalion, missile command (medium).

10. General Responsibilities of Artillery Units

Each artillery commander is responsible for seeing that required survey control is furnished to subordinate units as soon as possible.

11. Battalion (Separate Battery) Survey Responsibilities

The battalion (separate battery) survey officer plans, coordinates, and supervises battalion (battery) survey operations. Battalion (separate battery) survey personnel perform the survey operations necessary to establish—

- a. The grid coordinates and the height of—
 - (1) The battery center for each light, medium, and heavy artillery battery.
 - (2) The position of each weapon for very heavy artillery.
 - (3) The battery center for mortar battery or mortar platoon in applicable organization.
 - (4) The position of each launcher and, when required, guidance radar and orienting station for artillery missile battalions (separate battery).

b. An orienting line for each weapon position and missile guidance element when required and to compute the orienting angle for each weapon position.

c. The grid coordinates, the height, and a line of known direction for radar positions when so directed.

d. The grid coordinates, the height, and a line of known direction for each target area base observation post (OP) (always required for direct support artillery; as directed for other artillery).

e. The grid coordinates and the height of critical points in the target area; i.e., registration points, restitution points (always required

for direct support artillery; as directed for other artillery).

f. The grid coordinates, the height, and a line of known direction for additional points as directed by the battalion commander.

12. Division Artillery Survey Responsibility

The division artillery survey officer coordinates and supervises the survey operations of subordinate echelons. He establishes the division artillery survey information center (except for airborne division artillery). The division artillery survey party performs the survey operations necessary to establish—

a. The grid coordinates, the height, and a line of known direction for each—

- (1) Survey control point (SCP) for each organic or attached field artillery battalion and separate battery.
- (2) Division artillery observation post (when required).
- (3) Attached searchlight platoon survey control point in areas for which maps are not available.
- (4) Meteorological orienting station in areas for which large-scale maps are not available.
- (5) Additional point designated by the division artillery commander; e.g., a survey control point for a tank unit assigned an indirect fire mission.

b. The grid coordinates and heights of points in the target area as directed by the division artillery commander.

c. Declination stations as needed.

d. A line of known direction for meteorological orienting stations in areas for which large-scale maps are available (position can be inspected to required accuracy).

13. Field Artillery Target Acquisition Battalion Survey Responsibility

The field artillery target acquisition battalion coordinates the survey operations of lower echelons. To facilitate this coordination, the battalion establishes a corps survey information center (SIC), where records are maintained of all fourth order and higher survey control points existing in the corps area. The survey platoons within the battalion perform the survey operations necessary to establish—

a. The grid coordinates, the height, and a line of known direction for each—

- (1) Division artillery survey control point.
- (2) Corps artillery battalion (separate battery) survey control point.
- (3) Flash ranging observation post of the target acquisition battalion.
- (4) Counterbattery radar set of the target acquisition battalion.
- (5) Survey control point required for the searchlight battery (platoon) in areas for which maps are not available.
- (6) Additional points designated by the corps artillery commander; e.g., Air Force radio and radar installations located in the corps area, including target director posts.
- (7) Meteorological orienting station in areas for which large-scale maps are not available.
- (8) Drone platoon in areas for which maps are not available.

b. The ground location of each sound ranging microphone of the target acquisition battalion.

c. Declination stations as needed.

d. A line of known direction for meteorological orienting stations in areas for which large-scale maps are available (position can be inspected to required accuracy).

14. Air Defense Artillery Survey

The survey operations performed by an air defense artillery (ADA) unit are determined by the mission assigned to the unit.

a. The purpose of the survey operations of air defense artillery units assigned a ground support field artillery (FA) mission is to provide survey control that will permit the massing of fire, delivery of surprise observed fires, and delivery of effective unobserved fires. The survey operations performed are the same as those performed by a field artillery missile battalion.

b. The purpose of the survey operations of air defense artillery units assigned an air defense mission is to provide survey control that will permit the exchange of target information and that will insure the delivery of air defense fires outside the limits of restricted areas.

c. When suitable maps are available and there are no restricted areas, personnel and ADA gun battalions and ADA automatic weapons (AW) battalions with electronic fire control equipment must perform the survey operations necessary to establish the slant range from the track radar to the radar range-calibrating point for each battery.

d. When suitable maps are not available and/or when there are restricted areas, personnel of the ADA gun battalions perform the survey operations necessary to establish—

- (1) The grid coordinates, the heights, and the azimuth to an orienting point for the battalion surveillance radar and the track radar of each battery.
- (2) The slant range from each track radar to its radar range-calibrating point.
- (3) When directed, the distance from each track radar to the orienting point.

e. When suitable maps are not available and/or when there are restricted areas, personnel of ADA AW battalions (batteries) with electronic fire control equipment and personnel of 75-mm light ADA battalions (batteries) perform the survey operations necessary to establish—

- (1) The grid coordinates, the height, and

the azimuth to an orienting point for each weapon.

- (2) The slant range from each weapon to its radar range-calibrating point.

f. When suitable maps are not available, personnel of ADA AW battalions without electronic fire control equipment perform no survey operations except when there are restricted areas. When there are restricted areas, they perform the survey operations necessary to establish the grid coordinates, the height, and the azimuth to an azimuth mark for each fire unit.

g. The grid coordinates and the azimuth to an orienting point for the track radars of ADA missile batteries in an air defense role normally will be determined by engineer survey operations. However, personnel of semimobile ADA missile batteries may be required to determine these data by performing limited survey operations.

h. Personnel of ADA missile batteries assigned a ground support FA mission perform survey operations to determine the grid coordinates and height of track radars and an azimuth to an orienting point for each track radar. For further discussion of survey operations for air defense artillery unit refer to chapter 19.

PART TWO

SURVEYING EQUIPMENT AND PROCEDURES

CHAPTER 3

SURVEY EQUIPMENT

Section I. GENERAL

15. General

Survey equipment consists of instruments and accessories necessary to perform a survey. Survey instruments include those items of equipment with which measurements are made. Survey accessories include those items of equipment which assist in making measurements and in recording, computing, and plotting survey data.

16. Survey Instruments

a. The instruments employed in artillery surveying are—

- (1) Steel tape.
- (2) Aiming circle.
- (3) Transit.
- (4) Theodolite (FA units only).
- (5) Altimeter (FA units only).
- (6) Target set, surveying.
- (7) Tellurometer.
- (8) Surveying Instrument Azimuth Gyro Artillery.

b. The survey instruments in *a* above are discussed in chapters 4 through 12.

17. Survey Accessories

The accessories employed in artillery surveying are—

a. Taping equipment which includes—

- (1) Plumb bobs.
- (2) Steel arrows (taping pins).
- (3) Tension handles (certain FA units only).

(4) Clamping handles (certain FA units only).

(5) Hand levels (certain FA units only).

b. Station marking equipment which includes—

- (1) Ranging poles.
- (2) Ranging pole tripod (certain FA units only).
- (3) Levels for level rod (FA units only).
- (4) Target cloth.
- (5) Hatchets.
- (6) Wooden and/or steel stakes.

c. Recording and computing equipment which includes—

- (1) Notebooks.
- (2) Department of the Army forms.
- (3) Pencils.
- (4) Logarithmic and mathematical tables (TM 6-230 and/or Vega tables).
- (5) Army Ephemeris (TM 6-300-61).

d. Numerous items of miscellaneous equipment which include—

- (1) Star identifiers (certain FA units only).
- (2) Computing machines (certain FA units only).
- (3) Military slide rules (FA units only).

18. Surveying Equipments Sets

a. Field artillery units are issued angle-measuring instruments as separate items. Field artillery units authorized altimeters and/or computing machines are issued those items

separately. All other items of survey equipment, with the exception of forms and technical manuals, are issued to field artillery units in two surveying equipment sets. These sets are—

- (1) Artillery survey set, fourth order.

- (2) Artillery survey set, third order.

b. Artillery survey set, fourth order was designed for use by units performing survey with the aiming circle; artillery survey set, third order was designed for use by units using the theodolite or transit.

Section II. DISCUSSION OF SURVEY ACCESSORIES

19. General

a. Logarithmic tables are discussed in TM 6-230.

b. The military slide rule is discussed in TM 6-240.

c. Survey computation forms are explained in conjunction with the method of survey in which they are employed within this manual.

d. Other accessories which are used frequently are discussed in paragraphs 20 through 26.

20. Plumb Bob

The plumb bob is used in artillery surveying as a taping accessory and as an angle measuring instrument accessory. Most plumb bobs used consist of a body and removable cap made of brass and a replaceable point made of steel. The plumb bob used with the M2 aiming circle is of one-piece steel construction.

21. Taping Pins

Steel arrows, called taping pins, have a ring on one end and a sharp point on the other. These pins are issued in sets of 11. They are used to mark, temporarily, the positions of the ends of the tape on the ground as tape lengths are measured.

22. Tension Handle

The tension handle is used in training survey personnel to apply the correct amount of tension to a steel tape. This handle is a spring balance, graduated in pounds from 0 to 30. With prolonged use the spring of the tension handle will gradually stretch, causing erroneous

readings. It must therefore be tested occasionally with a weight of known value.

23. Clamping Handle

The clamping handle is used to hold and apply tension to the tape when a partial tape length is being measured.

24. Hand Level

The hand level is used to measure approximate differences in elevation. It is used in artillery survey to train taping personnel to recognize when the tape is held horizontal. This instrument consists of a metal sighting tube with plain glass covers at the ends and a level vial mounted on the tube. It is usually hand held in front of the eye. The landscape, level bubble, and index line can be seen in the tube.

25. Ranging Pole

The ranging pole is constructed of tubular steel. It consists of two interlocking sections, one of which is pointed. The length of the assembled pole is 6 feet, 6 inches. The pole is painted in six 1-foot sections which are alternately red and white. For storage, the pole is disassembled and placed in a canvas case.

26. Ranging Pole Tripod

The ranging pole tripod is used for holding a ranging pole over a survey station. In use, the tripod is set up so that the head of the tripod is approximately 3 inches horizontally from the survey point. The ranging pole is then placed in the collar of the adjustable arm. The pole is then made vertical by using the level for the level rod.

CHAPTER 4

TAPES AND TAPING

Section I. GENERAL

27. Tapes and Accessories

a. Field artillery survey personnel are equipped with 30-meter steel tapes for making linear measurements (taping). These tapes are graduated on one side only, in meters, decimeters (0.1 meter), and centimeters (0.01 meter) throughout, with the first decimeter graduated in millimeters (0.001 meter). There is a blank space at each end of the tape. A reel and two leather thongs are furnished with each tape.

b. In addition to a tape, each taping team should be equipped with 2 plumb bobs, 1 plumb bob and arrow holder, 1 clamping handle, 1 set of 11 arrows (taping pins), 1 hand level, 1 tension handle, 2 leather thongs, 2 notebooks, and 2 pencils (fig. 1).

28. Care of Steel Tapes

a. Steel tapes are accurate surveying instruments and must be handled with care. Although steel tapes are of durable construction, they can be easily damaged through improper care and use.

b. In use, the tape should be completely removed from its reel and kept straight to prevent its being kinked or broken. The tape

should never be pulled around an object that will put a sharp turn in the tape. Do not jerk the tape, step on it, or allow vehicles to run over it. If there is a loop in the tape, it may be kinked or broken when tension is applied. Before applying tension, the tapemen should see that the tape is not looped.

c. After use, the tape should be wiped clean and dry and then oiled lightly. The tape is oiled by running it through an oily rag as it is being reeled in. The tape should be loosely wound on its reel when not in use. In winding the tape on the reel, insert the end of the tape with the 30 meter graduations into the reel and wind the tape in such a manner as to cause the numbers to be wound facing the axle of the reel.

29. Repair of Broken Tape

a. A sheet metal sleeve coated on the inside with solder and flux is fitted over the broken ends of the tape and hammered down tightly. By applying heat, even from an ordinary match, the tape is securely fastened together.

b. The repaired section of the tape must be checked with another section of the tape to insure that the ends of the tape were placed together and that a true measurement can still be made.

Section II. TAPING PROCEDURES AND TECHNIQUES

30. Horizontal Taping, General

a. The method of taping used in artillery surveys is known as *horizontal taping*. In this method, all measurements are made with the tape held horizontally. The point *from which* the distance is to be measured is the *rear station*. The point *to which* the distance is to be

measured is the *forward station*. The distance between stations is usually several times greater than a full tape length. The taping team, starting at the rear station, determines the distance by measuring successive full tape lengths until the distance remaining is a partial tape length. This length is then measured.

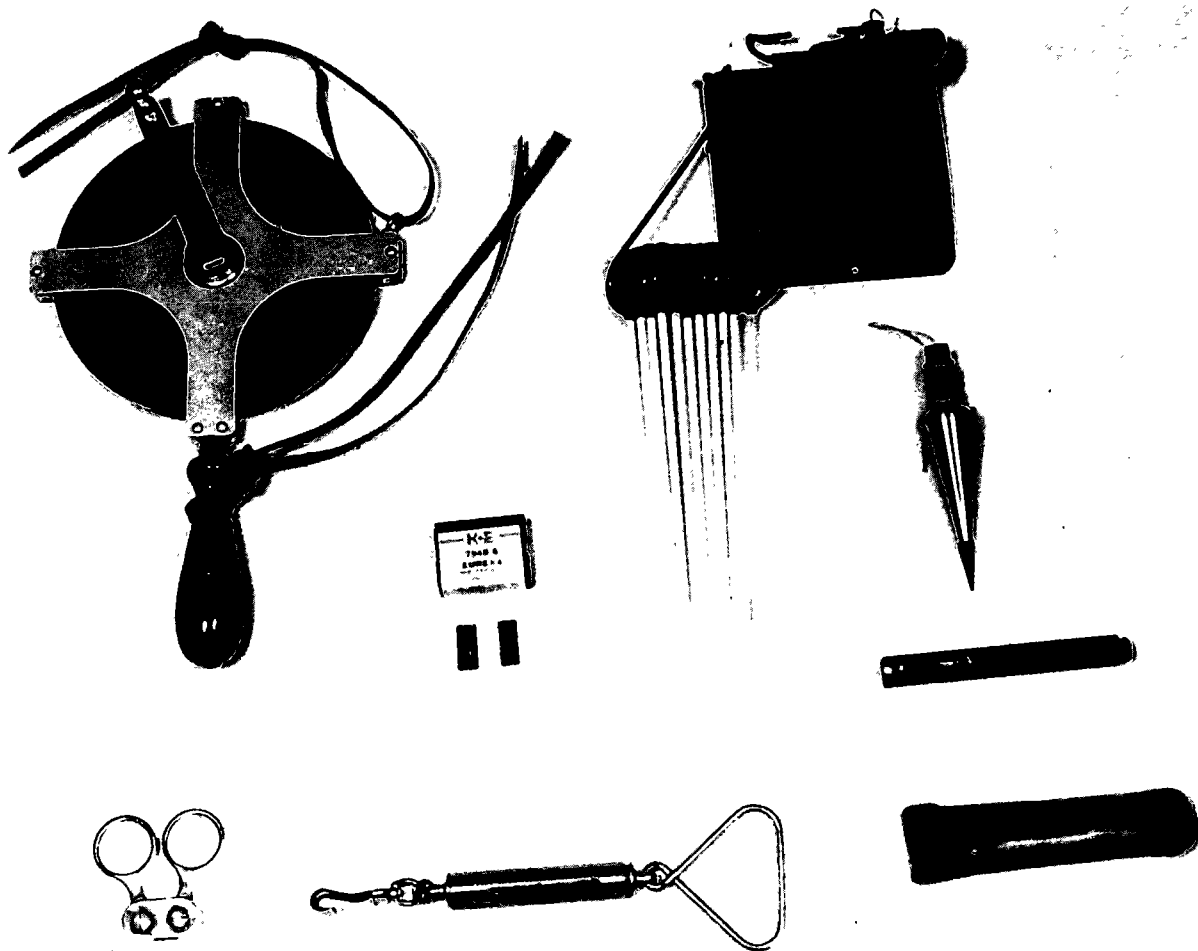


Figure 1. Taping equipment.

The distance between stations is determined by adding the product of the number of tape lengths and the length of the tape to the partial tape length. Each measurement is made with the tape held *horizontally* between the rear and forward stations.

b. A taping team consists of two men—a front tapeman and a rear tapeman. The rear tapeman commands the taping team. The rear tapeman determines and reports the distance measurement; *the front tapeman independently checks the distance measurement*. Additional personnel are required for taping at night.

31. Measuring First Full Tape Length

To measure the first full tape length—

a. The front tapeman gives one taping pin to the rear tapeman, keeping 10 pins in his

possession. The pin given to the rear tapeman represents the first full tape length. The front tapeman moves toward the forward station with the zero end of the tape.

b. As the end of the tape reaches the rear station, the front tapeman stops, either on the count of paces or on the command TAPE given by the rear tapeman. The rear tapeman sights along the tape toward the forward station and signals the direction that the front tapeman should move to align the tape, first with the forward station and then with an estimated horizontal plane. The tape must be aligned within .5 meter of the line-of-sight from one station to the succeeding station and within .5 meter of the horizontal plane.

c. Each tapeman places the leather thong on his wrist and the plumb bob cord on the proper graduation on the end of the tape. The rear

tapeman commands PULL and each tapeman exerts a pull of 25 pounds on the tape.

d. After the tapemen have properly alined and applied tension to the tape, the rear tapeman places his plumb bob exactly over the rear station and commands STICK. At this command, the front tapeman drops his plumb bob and then marks the point of impact with a taping pin. *When the pin has been placed in the ground, the front tapeman reports STUCK*, which instructs the rear tapeman to move forward to measure the next tape length.

e. When a team is taping on sloping ground void of brush and tall grass, the plumb bob need *not* be used at the uphill end of the tape. The end of the tape may be held immediately adjacent to the taping pin.

32. Measuring Succeeding Full Tape Lengths

To measure succeeding full tape lengths, the tapemen use the procedure discussed in paragraph 31, except as follows:

a. The front tapeman should obtain his approximate horizontal alinement by sighting along the tape at the rear station, moving right or left until the tape is approximately on line. (Final alinement is made as directed by the rear tapeman. However, if the rear tapeman cannot see the forward station, final alinement is made by either the instrument operator or

the front tapeman sighting back on the rear station, or by the rear tapeman through the use of intermediate points established in alinement with the forward station.)

b. The rear tapeman should place his plumb bob exactly over the point at which the taping pin enters the ground.

c. The rear tapeman pulls the taping pin from the ground before moving forward to the next pin position. *If a taping pin is lost during the measurement of the distance, the tapemen must make the entire measurement again, rather than complete the measurement from a recovered pin hole.*

33. Breaking Tape

To measure tape lengths when the tape cannot be alined with a horizontal plane within one-half meter (1½ ft.) because of the slope of the ground, the tapemen use a special procedure known as *breaking tape* (fig. 2). In breaking tape—

a. The front tapeman pulls the tape forward a full tape length, drops it approximately on line, and then comes back along the tape until he reaches a point at which a partial tape length, when held level, is not held above the armpits of the downslope tapeman. At this point, the front tapeman selects any convenient full meter graduation. The tapemen then meas-

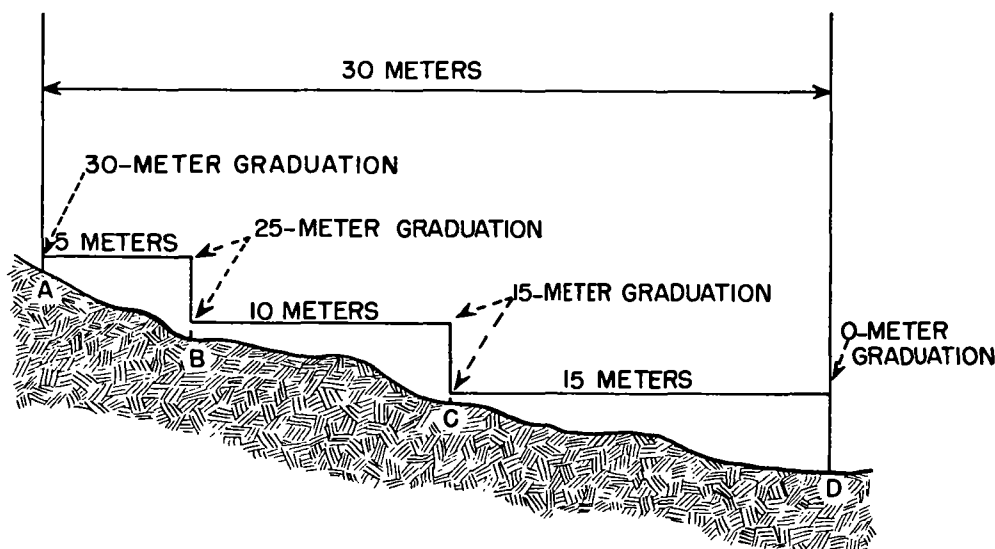


Figure 2. Breaking tape.

ure the partial tape length, applying the full 25 pounds tension to the tape.

b. After he has placed the taping pin, the front tapeman waits until the rear tapeman has come forward. The front tapeman tells the rear tapeman which full meter graduation was used, e.g., "Holding 25," which is repeated by the rear tapeman. He receives a pin from the rear tapeman and moves forward, repeating this procedure until the zero mark is reached.

c. *When holding a point on the tape other than the zero graduation, the front tapeman must receive a pin from the rear tapeman before moving forward.*

34. Measuring Distances in Excess of 10 Tape Lengths

To measure a distance longer than 10 full tape lengths, the tapemen use the procedures discussed in paragraphs 31 through 33 except as follows:

a. When the front tapeman has set his last pin in the ground, he has established a point which is 10 full tape lengths from the rear station. The front tapeman waits at the last pin position until the rear tapeman comes forward.

b. *Both tapemen count the pins to verify that none have been lost.* (One pin is in the ground; 10 pins should be in the possession of the rear tapeman.)

c. The rear tapeman gives the front tapeman the 10 pins.

d. Both tapemen record 10 tape lengths, and then continue taping.

35. Measuring Partial Tape Lengths

To measure the partial tape length between the forward station and the taping pin representing the last full tape length, the tapemen use the following procedure:

a. The front tapeman moves to the forward station and places the plumb bob cord on the zero graduation of the tape. The rear tapeman moves forward along the tape to the taping pin.

b. If slack is needed, the front tapeman commands SLACK and the rear tapeman allows the tape to move forward. When the front tapeman is ready, he commands PULL and the rear tapeman exerts a pull of 25 pounds on the tape, using the clamping handle to hold the tape. As he applies tension to the tape, the rear tapeman slides his plumb bob cord along

the tape until the plumb bob is exactly over the pin.

c. When the zero graduation is exactly over the forward station, the front tapeman commands READ. The rear tapeman reads the graduation marked by the plumb bob cord and announces the measurement of the partial tape length to the nearest 0.01 meter.

d. The front tapeman repeats the reading aloud, and both tapemen record the measurement.

36. Determining Taped Distance

To determine and check the distance measurement (fig. 3)—

a. Each tapeman counts the number of pins in his possession. *(The pin in the ground at the last full tape length is not counted.)*

b. The rear tapeman determines the distance measurement by multiplying the length of the tape (30 meters) by the number of full tape lengths measured and adding the partial length read from the tape. (The number of full tape lengths measured is equal to the number of taping pins in his possession plus 10 for each exchange of pins.)

c. The front tapeman independently checks the distance measurement by multiplying the number of full tape lengths by the length of the tape and adding the partial tape length. (The number of full tape lengths is equal to 10 for each exchange of pins plus the difference between 10 and the number of pins in his possession.)

d. The rear tapeman reports the distance measurement to the recorder or the chief of party.

37. Taping at an Occupied Station

When a taping team is making a measurement at a station occupied by an instrument, the tapeman at the station must be careful not to disturb the instrument. If a plumb bob is used with the instrument, the tapeman can make his measurement at the plumb bob cord of the instrument.

38. Use of Two Taping Teams

When two taping teams are used to measure the distance between two stations, one taping team uses a pin to establish a starting station a half tape length (15 meters) from the rear station. In this case, the front tapeman does

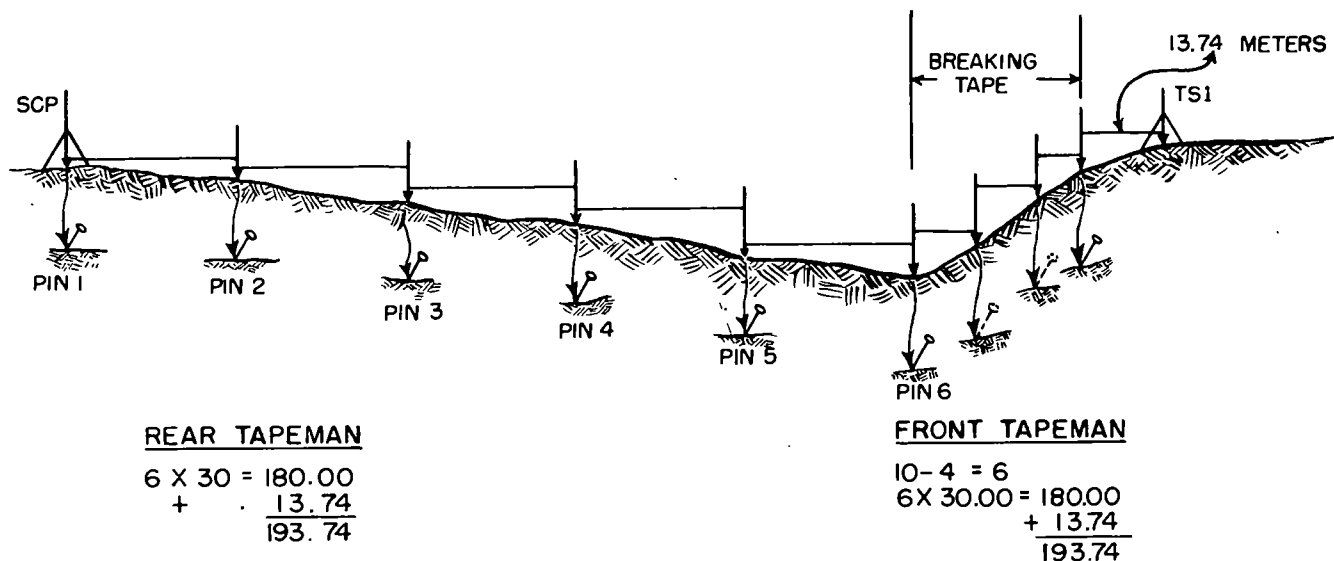


Figure 3. Determining taped distance.

not give a pin to the rear tapeman. The taping pin marking the half tape length represents one full tape length plus 15 meters. After the starting station is established a half tape length from the rear station, the taping procedures followed are the same as those discussed in paragraphs 31 through 37, except that each tapeman adds 15 meters to the distance measurement. (This procedure precludes both teams placing their taping pins in the same hole.)

39. Taping at Night

Daytime taping methods may be used at night with certain modifications. A piece of white cloth should be tied to each end of the tape to assist the tapemen in following and locating the tape. Three men should be added to each taping team. One man accompanies each tapeman as a light holder; the third man marks the taping pin. When the rear tapeman comes to the taping pin, the third man walks the length of the tape, freeing it from any obstructions. This procedure is repeated for each full or partial tape length. Light holders must take necessary security measures with their lights.

40. Moving Forward

a. The front tapeman should select a landmark (rock, bush, etc.) in line with the forward station. In moving forward, the front

tapeman keeps his eyes on the line to the forward station and should not look back. He should determine the number of paces to the tape length so that he can stop without being signaled when he has moved forward a tape length.

b. By moving forward at a point 2 or 3 meters in front of the rear end of the tape, the rear tapeman can usually locate the taping pin by the time the front tapeman has stopped.

c. When there is an instrument used at either the forward or the rear station, the tapemen will remain clear of the line of sight.

41. Tape Alinement

The tapemen must carefully aline the tape. The maximum allowable error in both horizontal and vertical alinement is one-half meter for a full 30-meter tape length. The tapemen aline the tape with the stations which establish the line by sighting along the tape toward the stations at each end of the line (fig. 4). The tapemen then make the tape horizontal by holding it parallel to an estimated horizontal plane. If difficulty is encountered in keeping the tape level in rough terrain, then the hand level should be used. To use the hand level to establish a horizontal plane, the downslope tapeman—

a. Sights through the level at the upslope tapeman.

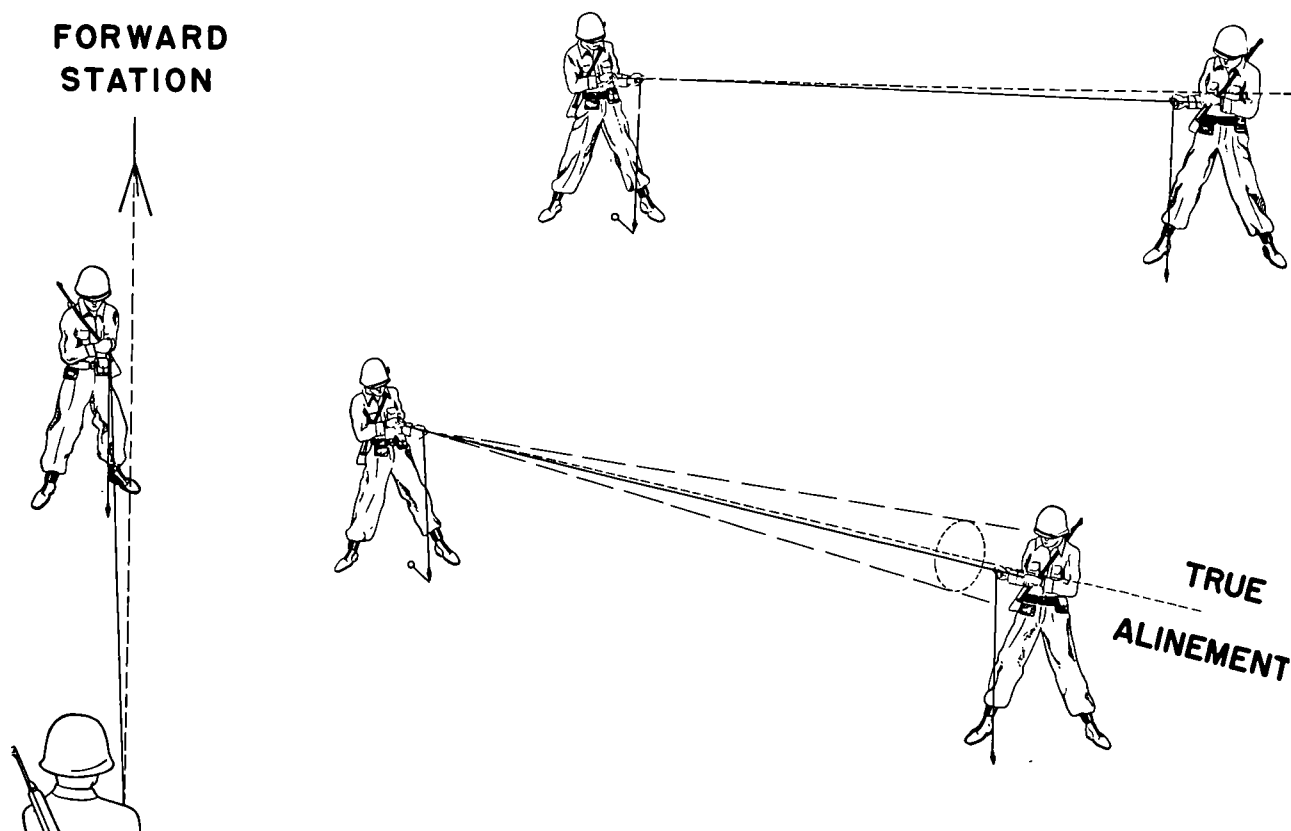


Figure 4. Tape alinement.

b. Raises or lowers the objective end of the hand level until the image of the level bubble is centered on the center horizontal crossline.

c. Determines the point on the upslope tapeman which is level with his eye. (The horizontal plane is established.)

d. Instructs the upslope tapeman how to hold his end of the tape so that the tape will be parallel to the established horizontal plane. (*The downslope tapeman must not hold the tape higher than his armpits. Both tape ends should be held the same distance below the established horizontal plane.*)

Note. The tapemen should check the accuracy of the bubble of the hand level when it is first used each day. This is accomplished by having the upslope tapeman use the hand level to sight back at the downslope tapeman to verify the established horizontal plane.

42. Applying Tension to Tape

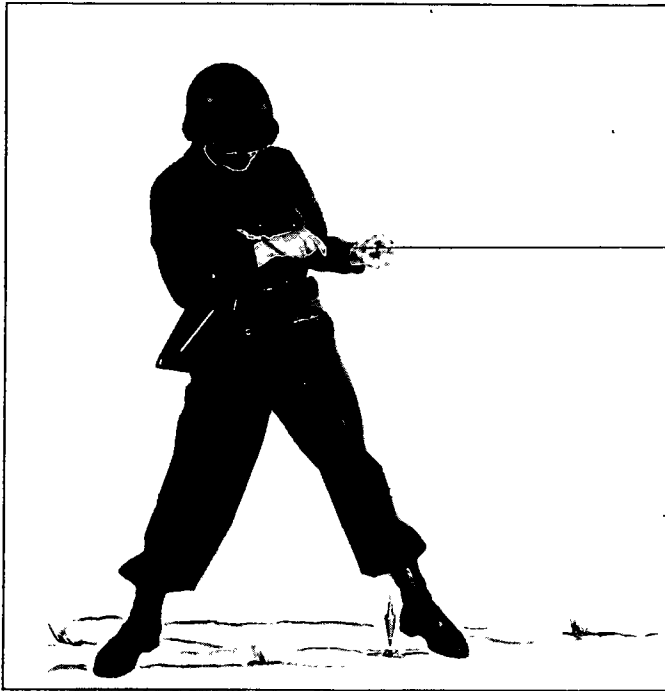
The tapemen must apply 25 pounds tension (pull) to each full or partial tape length.

a. The tapemen should apply tension to the

tape by using the leg muscles and the large muscles of the back. To do this, the tapeman faces across the tape with his shoulders parallel to the length of the tape, passes the hand of one arm through a loop in the thong, and places the elbow of that arm tight against some part of his body (fig. 5). When the tapeman is standing, he applies tension by bending the knee away from the other tapeman, causing the weight of the body to push against the arm holding the tape. When the tapeman is kneeling, he applies tension by pushing the knee which is away from the other tapeman against the arm holding the tape.

b. The clamping handle is used to hold the tape at any point other than a tape end. *In order to avoid kinking the tape, the tapeman should hold the clamping handle with the index and middle fingers.* Normally, the handle will clamp as tension is applied to the tape. If additional pressure is required, it is applied to the

REAR TAPEMAN



FRONT TAPEMAN



Figure 5. Applying tension to a tape.

outside of the finger grips by using the thumb and ring finger.

c. The tension handle (a scale which measures tension in pounds) should be used by the front tapeman until both tapemen become accustomed to the "feel" of 25 pounds tension.

43. Use of Plumb Bobs

The tapemen use plumb bobs to project points on the tape to the ground. Each tapeman holds the plumb bob cord on the proper tape graduation with the thumb of one hand on the cord and the forefinger of that hand beneath the tape (fig. 5). After alining the tape and applying tension to it, each tapeman lowers the plumb bob by letting the cord slip across the tape until the tip of the plumb bob is approximately one-fourth inch above the desired point. Swinging of the plumb bob is eliminated by gently lowering the tape until the plumb bob tip touches the ground and then slowly raising it.

a. The rear tapeman uses the plumb bob to establish his end of the tape directly over the point from which each tape length is measured.

b. The front tapeman uses the plumb bob to

establish the point on the ground to which each length is measured by dropping his plumb bob. After establishing the point with the plumb bob, the front tapeman marks that point with a taping pin. (The rear tapeman can locate each pin more readily if the front tapeman *has cleared the ground of grass, leaves, etc., by kicking a groove in the ground.*)

44. Use of Taping Pins

The tapeman must use the taping pins to mark points on the ground for each full or partial tape length. The front tapeman marks the point struck by the plumb bob by sticking the pin into the ground at exactly the point where the tip of the plumb bob hit. The shaft of the pin should be placed at about a 45° angle with the ground and perpendicular to the length of the tape. (*When moving forward, the tapemen should not pull the tape through the loop of the taping pin.*) When taping over a hard surface, it may be necessary to mark the point struck by the plumb bob in an identifiable fashion (point of arrow or pencil) and the point of the arrow should be laid at the point struck by the plumb bob, perpendicular to the line of direction of the tape.

Section III. ACCURACY AND ERRORS

45. Comparative Accuracy for Double-Taped Distances

a. When the distance between two stations has been determined by double-taping, the two measurements are compared and the *comparative accuracy* for the two measurements is determined. Comparative accuracy is expressed as a ratio between the difference in the measurements and the mean of the measurements. The ratio is expressed with a numerator of one; e.g., 1/1,000 or 1:1000. The denominator is determined by dividing the mean of the measurements by the difference in the measurements. After computing the comparative accuracy, the denominator of the fraction is always reduced to the next lower hundred.

b. An example of the computation of a comparative accuracy for a distance measurement is as follows:

Distance measurement by	
taping team no. 1	= 357.84 meters
Distance measurement by	
taping team no. 2	= 357.76 meters
Difference between	
measurements	= 0.08 meters
Mean of the measurements	= 357.80 meters
Comparative accuracy =	
$\frac{1}{357.80 \div 0.08}$	$= \frac{1}{4472} = \frac{1}{4400}$

c. Certain comparative accuracies for double-taped distances are prescribed in subsequent chapters of this manual.

46. Errors in Horizontal Taping

Horizontal taping errors are of three categories as follows:

- Systematic errors.
- Accidental errors.
- Errors caused by blunders.

47. Systematic Errors

Systematic errors are errors which apply in the same direction.

a. The systematic errors encountered in horizontal taping cause distances to be measured longer or shorter than their true lengths. The principal causes of systematic errors are—

- (1) Failure to aline the tape properly.
- (2) Failure to apply sufficient tension to the tape.

- (3) Kinks in the tape.

b. Systematic errors can be eliminated or minimized by strict adherence to proper procedures and techniques. Tapemen should be especially attentive to keeping the tape horizontal when taping on a slope and should break tape when necessary. They should avoid the tendency to hold the tape parallel to the slope. When taping in strong winds, tapemen must be especially careful to apply the proper tension to the tape. Tapes should be checked frequently for kinks. One of the chief causes for kinked tapes is improper use of the clamping handle.

c. Systematic errors can be due to improper repair of the tape (repaired too long or too short), causing taped distances to be longer or shorter than their true distances.

48. Accidental Errors

Accidental errors are errors which may apply in either direction. Accidental errors are usually small in magnitude when compared with systematic errors. The principal accidental error encountered in taping is caused by small errors in plumbing. When taping, tapemen should be careful in plumbing over points. When taping in strong winds, tapemen must be especially careful to minimize swinging of the plumb bob cord. This can be accomplished by keeping the plumb bob close to the ground.

49. Errors Caused by Blunders

Blunders are mistakes made by personnel. They result in errors which are usually large in magnitude.

a. The principal blunders made by tapemen are—

- (1) An incorrect exchange in taping pins.
- (2) An error in reading the tape.
- (3) An omission of the half tape length when double-taping with two teams.
- (4) Loss of a taping pin.

b. Blunders can be detected and eliminated by strict adherence to proper procedures and by adoption of a system of checks; e.g., by double-taping, by pacing each taped distance, and, in some cases, by plotting the grid coordinates of the stations on a large-scale map.

CHAPTER 5

AIMING CIRCLE M2

Section I. GENERAL

50. General

The aiming circle M2 (fig. 6) is employed to obtain angular values in artillery surveys executed to an accuracy of 1:500 (target area base only). It is essentially a fixed-focus low-power telescope mounted on a composite body (fig. 7) containing a magnetic compass and leveling screws for establishing a horizontal plane. The instrument proper is supported by a base plate for mounting on a tripod. Angular measurements in azimuth and elevation are indicated on graduated scales and associated micrometers.

51. Aiming Circle Body

The aiming circle body is made up of four composite parts—the telescope body assembly, the body assembly, the worm housing, and the base plate assembly (fig. 7).

a. The telescope body assembly consists of the optical system, the vertical level vial, the reflector, and a neutral filter.

- (1) The optical system forms a 4-power, fixed-focus telescope. The reticle of the telescope (fig. 8) has a horizontal and a vertical crossline etched on it. The horizontal and vertical crosslines are graduated every 5 mils from 0 to 85 mils and are numbered every 10 mils. These graduations are used to measure relatively small deviations in azimuth and elevation from a reference line (e.g., high-burst registration). The telescope eyepiece (fig. 9) is inclined upward at an angle of 45° from the axis of the telescope to permit the observer to look down into the telescope while standing erect. The

objective end of the telescope is beveled to form a permanent sunshade.

- (2) The vertical level vial is positioned on the left side of the telescope. This level is used to establish a horizontal plane when reading deviations in elevations using the reticle. The lugs supporting the telescope level vial form an open sight with which to aline the instrument approximately on a station.
 - (3) The reflector is a plastic signal mounted on top of the telescope and at the vertical axis of the instrument. The reflector is used as a target for other instruments sighting on the aiming circle. At night, the reflector can be illuminated externally by use of the instrument light.
 - (4) A neutral filter is provided for viewing the sun directly for astronomic observation. The filter is slipped onto the eyepiece end of the telescope for observing the sun and is attached to the side of the telescope body when not in use.
- b. The body assembly consists of the azimuth and elevation worm mechanisms, the magnetic compass, the compass reticle, the compass needle actuating lever, and two horizontal plate levels.
- (1) The azimuth mechanism of the instrument has a fast and a slow motion. Horizontal angles are read in two parts; the hundreds of mils are read from the azimuth scale, and the tens and units of mils are read from the

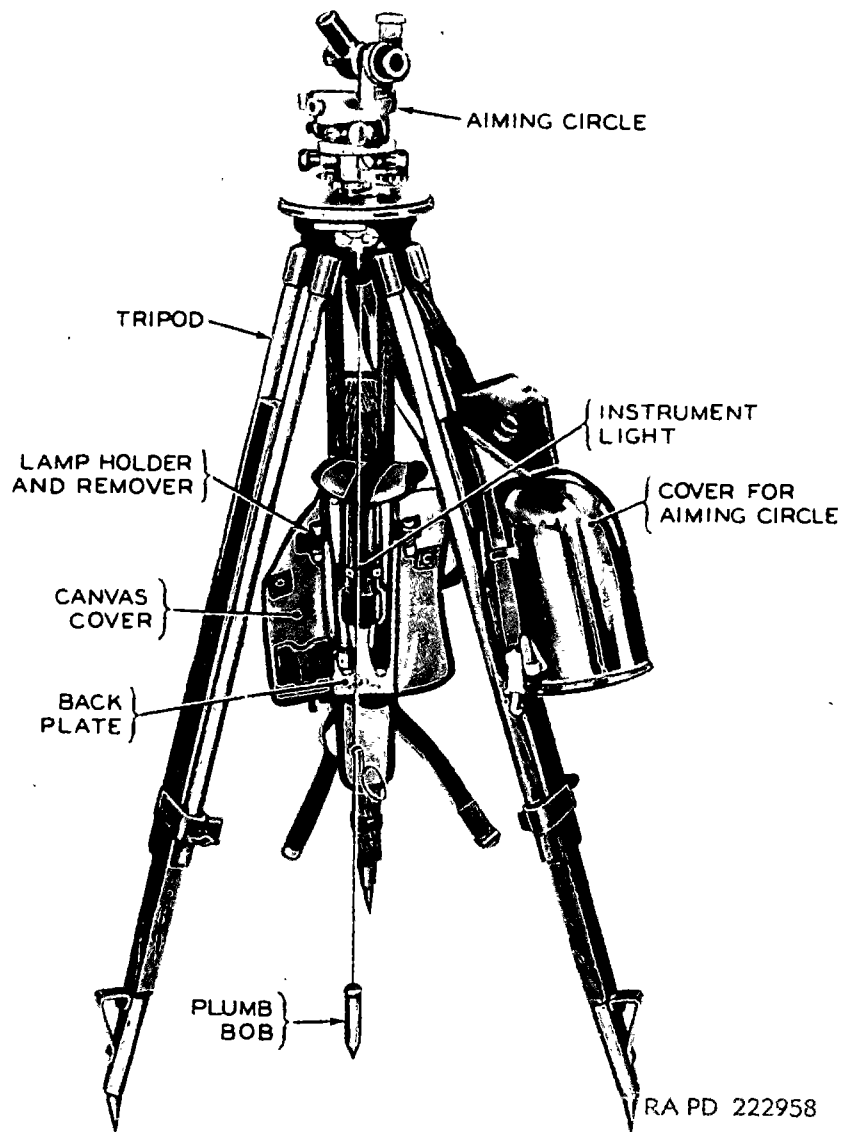


Figure 6. Aiming circle with equipment.

azimuth micrometer. The azimuth scale is graduated every 100 mils from 0 to 6,400 mils and is numbered every 200 mils. The 3,200 and 6,400 portion of the azimuth scale has a second scale (numbered in red from 0 to 3,200) below the primary azimuth scale. The graduations of the primary (upper) azimuth scale are used for survey. The second (lower) scale is used for laying the weapons of the firing battery. *This*

lower scale is not used in survey. The azimuth micrometer scale is located on the azimuth knob. It is graduated every 1 mil from 0 to 100 mils and is numbered every 10 mils.

- (2) The elevation mechanism of the aiming circle is similar to the slow azimuth motion. Stop rings in the mechanism prevent the telescope from striking the body assembly. Vertical angles from minus 440 mils to plus

FOUR MAJOR PARTS OF THE AIMING CIRCLE BODY

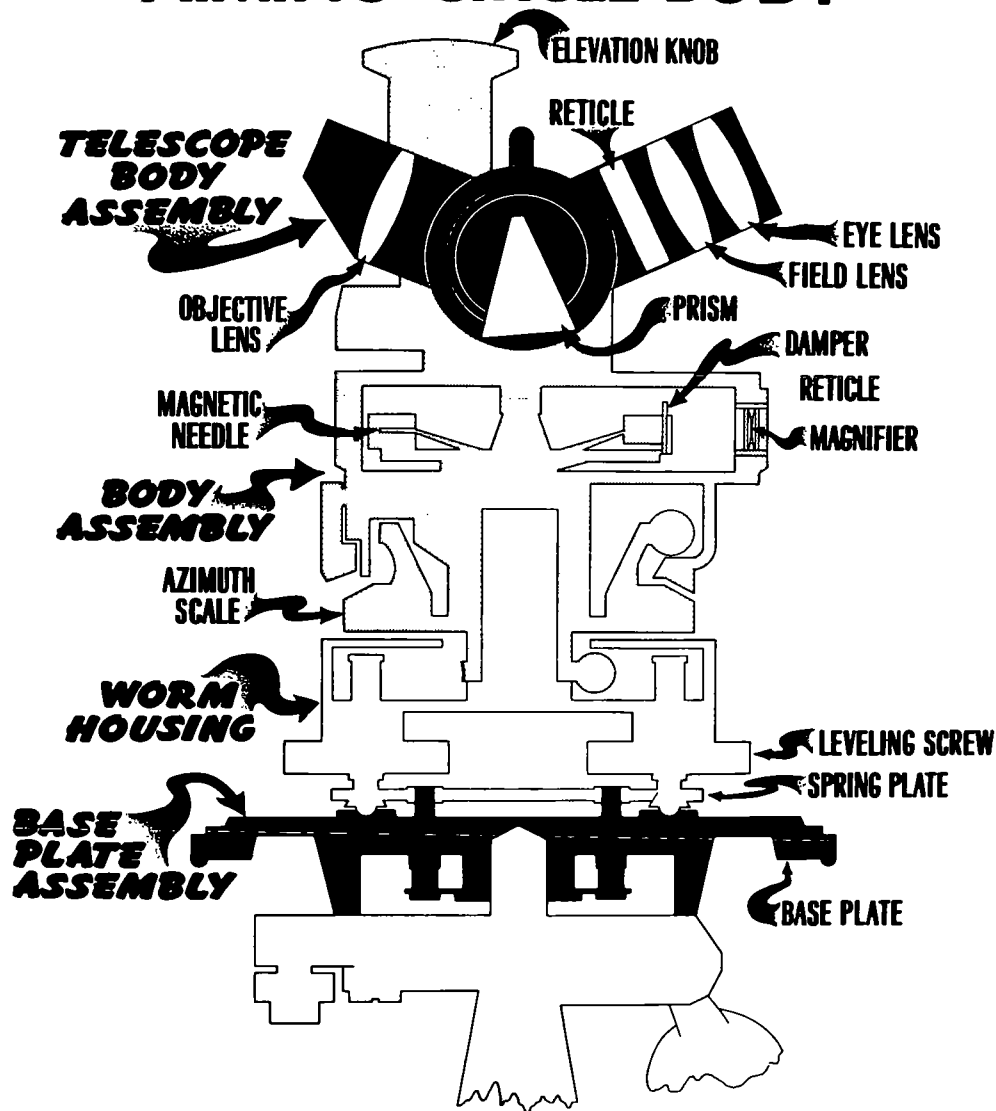


Figure 7. Schematic cutaway drawing of an aiming circle showing composite parts.

805 mils can be measured with the aiming circle. Vertical angles are read in two parts; the hundreds of mils are read from the elevation scale and the tens and units of mils are read from the elevation micrometer scale. The elevation scale is graduated and numbered every 100 mils from minus 400 mils to plus 800 mils. The plus symbol and minus symbol are not shown, but the minus numerals are shown in red and the plus numerals are shown in black. The elevation

micrometer scale is graduated every mil from 0 to 100 mils. The scales are numbered every 10 mils from left to right in black numerals and from right to left in red numerals. The red numerals on the elevation micrometer scale are used in conjunction with the red numerals on the elevation scale. The black numerals on the micrometer scale are used with the black numerals on the elevation scale.

- (3) The magnetic compass is located in the oblong recess in the top of the

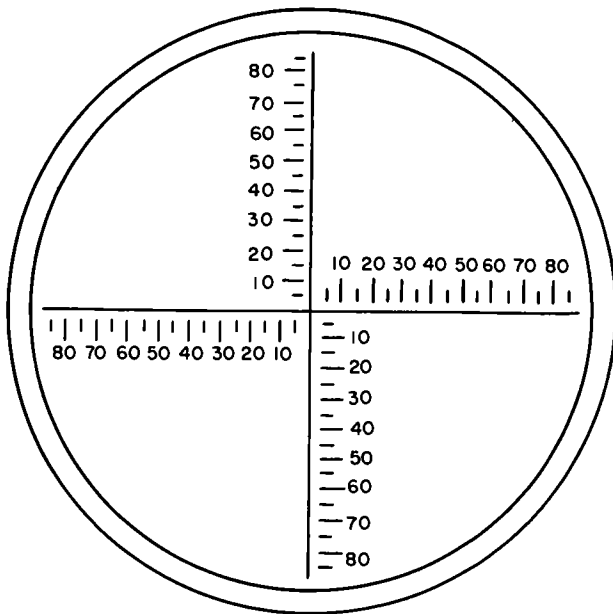


Figure 8. Telescope reticle as viewed in telescope.

body assembly. The magnetic needle is provided with copper dampers to aid in settling the needle quickly. A

small glass magnifier and a reticle with three etched lines on it are at one end of the recess (south end of the magnetic needle) to aid in alining the end of the needle. On the opposite end of the recess is an actuating lever which locks or unlocks the magnetic needle. When the lever is in a vertical position, the needle is locked. When the lever is turned to the right or the left, the needle is unlocked.

- (4) The aiming circle has two plate levels. One is a circular level vial for initial rough leveling, the other is a tubular level vial used to accurately level the instrument.

c. The worm housing is that portion of the aiming circle below the azimuth scale and above the base plate. It consists of the worm gear of the orienting (nonrecording) motion, the leveling screws, and the spring plate. The orienting knob which controls the nonrecording (lower) motion of the aiming circle is similar to the azimuth (recording) motion in that the orienting motion is permitted fast movement by lateral movement of the left orienting knob.

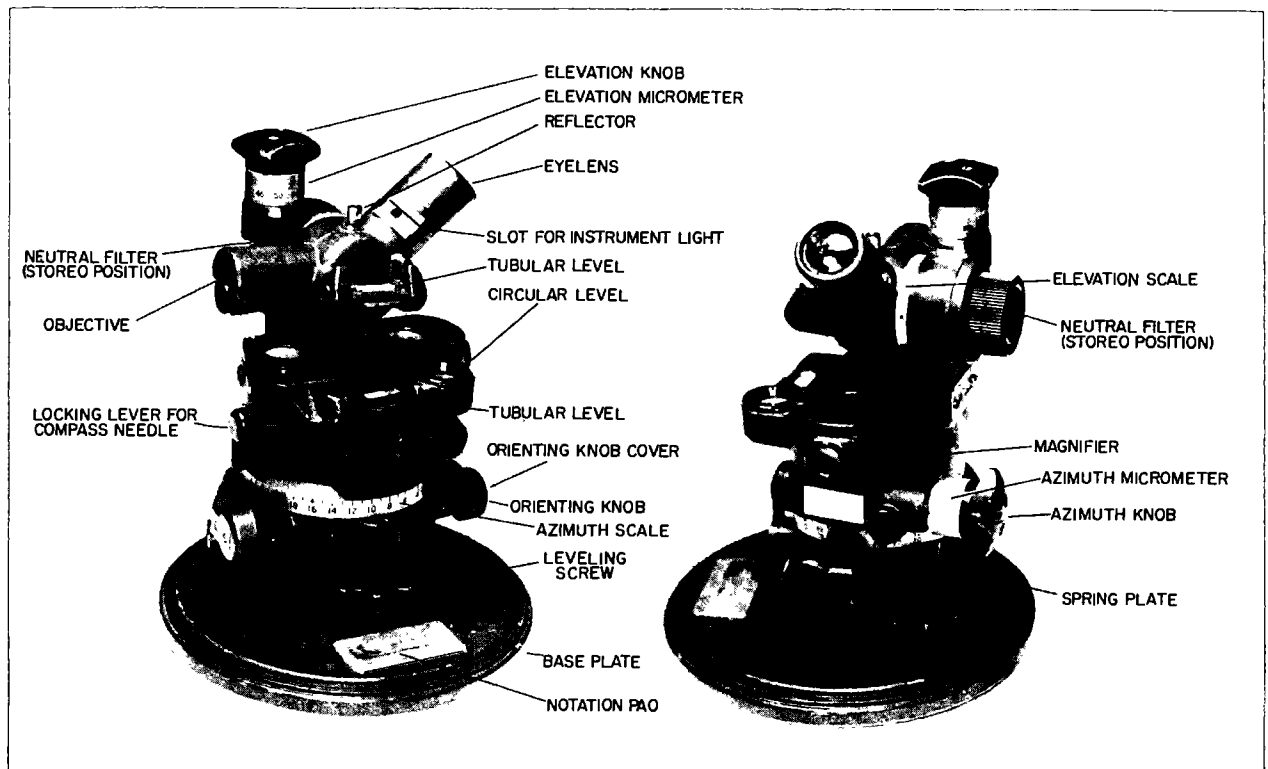


Figure 9. Aiming circle.

The two orienting knobs should be used simultaneously for slow movement of the orienting motion. Caps are provided for the orienting knobs when they are not in use to preclude use of the orienting motion by mistake. The leveling screws are attached to a spring plate which is attached to the base plate.

d. The base plate assembly is the base of the instrument when it is mounted on the tripod, and it is also the base of the carrying case. It is a flat plate to which the instrument is fixed. On the underneath side is a socket into which the tripod screw is threaded to attach the instrument to the tripod. A latch type cover is

provided to keep the socket clean and clear from obstruction when the instrument is not attached to the tripod. The base plate is fitted with a rubber washer, which makes a watertight seal when the cover is latched to it.

52. Aiming Circle Accessory Equipment

The accessory equipment (fig. 10) for the aiming circle consists of the tripod, backplate with canvas cover, instrument light, plumb bob, lamp holder and remover, and carrying case cover.

a. The tripod (fig. 6) has three telescoping legs, an aluminum head and cover, and a carry-

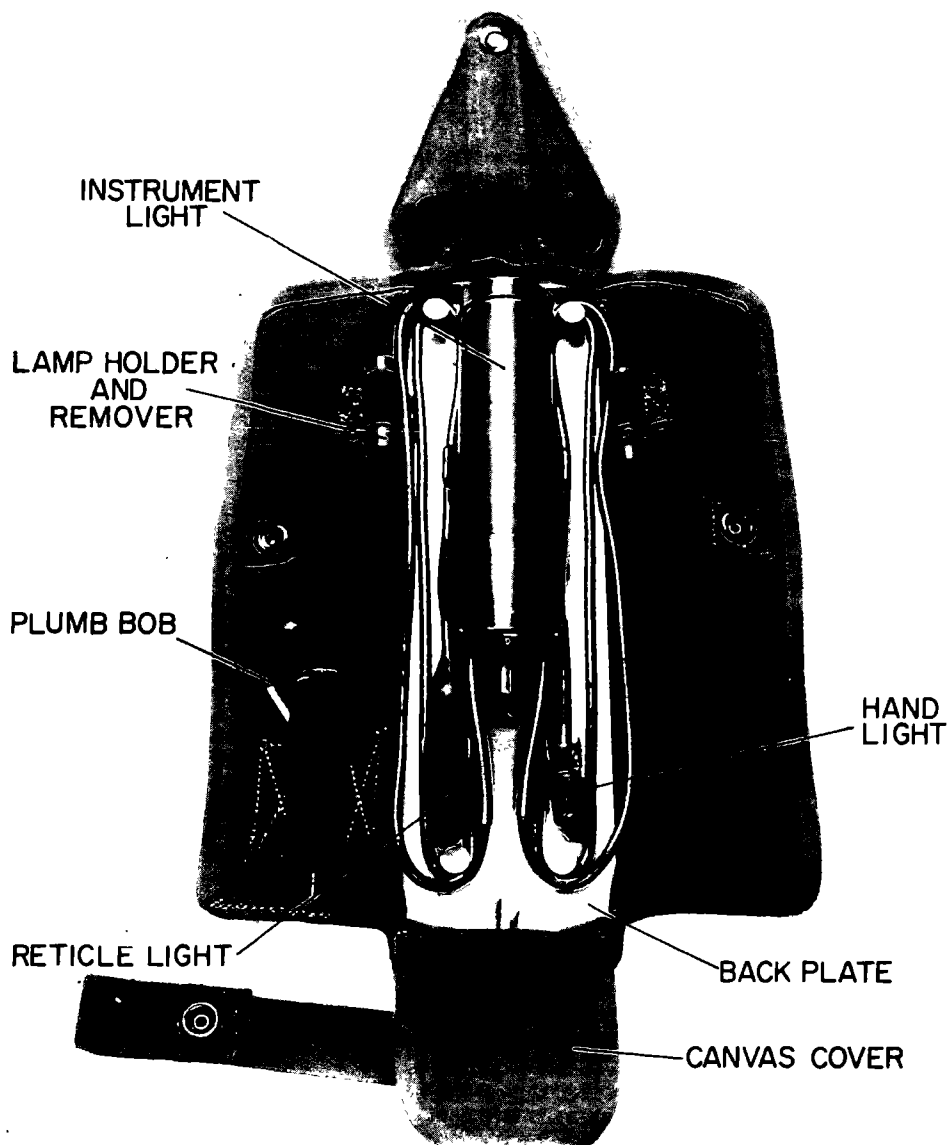


Figure 10. Accessory kit.

ing strap. The legs are adjusted and held in place by means of leg clamp thumbscrews. The leg hinges at the tripod head are adjusted for friction by clamping screws. The ends of the legs of the tripod are fitted with an aluminum boot and a bronze spike for ease in embedding the legs in the ground. The carrying strap is provided for carrying the tripod when the legs are retracted and strapped together.

b. The backplate and cover (fig. 10) are held to one of the tripod legs by two clamps. The backplate cover is the case for the instrument light, the plumb bob, and the lamp holder and remover.

c. The instrument light consists of a battery tube containing two flashlight batteries and two flexible cords. One of these cords carries the current to the telescope through a lamp bracket assembly that fits into a slot on the telescope. The other cord is attached to a hand

light assembly for general illumination around the instrument (leveling and reading the scales) and to illuminate the reflector. The degree of light is regulated by a rheostat located on the battery tube. The battery tube is held to the back by means of a clamp.

d. When in use, the plumb bob is suspended from a hook in the tripod screw. When the plumb bob is not in use, it is stored in a loop in the canvas cover of the accessory kit.

e. The lamp holder and remover is a small rubber tubular accessory, which is used for storing spare lamps and for removing burned out bulbs from their sockets.

f. The cover of the carrying case is a lightweight dome-shaped piece which is clamped to the base plate to provide a waterproof case for the instrument. The cover is provided with a carrying strap and two strong clamps for securing the cover to the base plate.

Section II. USE OF AIMING CIRCLE

53. Setting up the Aiming Circle

The procedure for setting up the aiming circle is as follows:

a. Unstrap the legs of the tripod. Loosen the leg clamp thumbscrews and extend the tripod legs to the desired length. Tighten the thumbscrews slightly (enough to hold the legs in place). Embed each leg firmly in the ground, making sure that the tripod head is approximately level and approximately over the point at which the angles are to be measured. Then firmly tighten the leg clamp thumbscrews, and remove the tripod head cover.

b. Open the base plate latch cover and thread the tripod screw into the aiming circle until it is firmly seated. Unsnap the aiming circle cover latches, remove the cover, and hang it on one of the tripod legs.

c. Attach the plumb bob and extend it so that it hangs about an inch above the point over which the instrument is to be set. If the plumb bob is within half an inch (laterally) of the point, it can be brought to the point by loosening the tripod screw and shifting the instrument on the tripod. If the plumb bob is more than half an inch from the point, the tripod legs may be adjusted to bring the plumb bob to the point. If this is not possible, then the

instrument and tripod should be picked up as a unit and moved until the plumb bob hangs within half an inch of the point.

d. Level the instrument by using the procedure specified in paragraph 54.

54. Leveling the Aiming Circle

The procedure for leveling the aiming circle is as follows:

a. Obtain a rough level by using the circular vial attached to the magnetic needle housing. Place the tubular level vial parallel to two leveling screws. Center the bubble by using these two leveling screws. Grasp the leveling screws between the thumb and forefinger of each hand. Turn the screws so that the thumbs of both hands move either toward each other or away from each other at the same time. This movement tightens one screw as it loosens the other. The bubble always moves in the same direction as the left thumb.

b. Rotate the instrument 1,600 mils and center the bubble by turning the third leveling screw.

c. Return the instrument to the first position and releve the bubble if necessary.

d. Return the instrument to the second position and releve the bubble if necessary.

e. Repeat *c* and *d* above until the bubble is centered in both positions.

f. Rotate the instrument 3,200 mils from the first position; if the bubble is not centered, bring the bubble halfway to the center by turning the same two leveling screws used to level the instrument in the first position (*a* above).

g. Rotate the instrument 3,200 mils from the second position. If the bubble is not centered, bring the bubble halfway to the center by turning the third leveling screw.

h. Rotate the instrument through 6,400 mils. If the bubble does not move more than one graduation, the instrument is considered level. If the bubble does move more than one graduation, the leveling procedure should be repeated. If, after repeated attempts, the instrument cannot be rotated throughout 6,400 mils without causing the bubble to move more than one graduation from the position obtained after completion of *a* through *g* above, the instrument should be turned in for repair.

55. Taking Down the Aiming Circle

The procedure for taking down the aiming circle is as follows:

- a.* Tighten leveling screws to their stops.
- b.* Lock the magnetic needle.
- c.* Place the azimuth knob over the notation strip.
- d.* Unhook the plum bob and replace it in the backplate cover.
- e.* Close the backplate cover.
- f.* Place the carrying case cover over the aiming circle and latch the cover locks.
- g.* Unscrew the tripod screw and remove the instrument from the tripod.
- h.* Replace the tripod head cover.
- i.* Collapse the tripod legs and tighten the thumbscrews.
- j.* Strap the tripod legs together.

56. Measuring Horizontal Angles

In artillery survey, horizontal angles are measured at the occupied station in a clockwise direction from the rear station. Horizontal angles are always read to the lowest visible point at the forward and rear stations. In sighting on a station, the vertical crossline is placed so that it bisects the ranging pole. The

procedure for measuring horizontal angles is as follows:

- a.* Set up and level the aiming circle.
- b.* Zero the azimuth and micrometer scales.
- c.* Sight approximately on the rear station by using the fast lower (nonrecording) motion.
- d.* Place the crossline exactly on the rear station by using the slow lower (nonrecording) motion. The last motion coming onto the station should be from left to right to reduce backlash. Close the orienting knob covers.
- e.* Disengage the azimuth (recording) control knob and rotate the aiming circle to bring the crosslines near the forward station but keeping them to the left of the station.
- f.* Release the azimuth control knob, allowing the mechanism to reengage. Using the slow motion of the azimuth control knob, bring the crosslines exactly to the point from left to right.
- g.* Read and record the value of the angle on the azimuth and micrometer scales to the nearest 0.5 mil.
- h.* With this value still on the scales, repeat *c* through *f* above.
- i.* Read and record the accumulated value of the two measurements of the angle to the nearest 0.5 mil.
- j.* Divide the accumulated value by 2. If the second value of the angle is smaller than the first, add 6,400 to the second value before dividing by 2. The mean value should agree with the first reading by 0.5 mil; if not, the angle must be remeasured.

57. Measuring Vertical Angles

Vertical angles are measured in conjunction with horizontal angles. Usually, a vertical angle is measured each time a horizontal angle is measured. Vertical angles, if possible, are measured to height of instrument (HI) at each forward station. The height of instrument is measured on a ranging pole. If the instrument operator constantly sets up the instrument at a certain height, a constant height of instrument may be used throughout a traverse. The procedure for measuring vertical angles is as follows:

- a.* Set up and level the aiming circle.
- b.* After the first repetition of the horizontal angle is measured, place the horizontal crossline at the height of instrument on the

forward station by using the elevation control knob while keeping the vertical crossline on the station.

c. Read and record the value of the vertical angle to the nearest 0.5 mil. If the black numerals are used, the vertical angle is plus; if the red numerals are used, the vertical angle is minus.

d. After the second repetition of the horizontal angle is measured, measure the vertical angle a second time.

e. Determine the mean vertical angle by adding the first and second reading of the vertical angle and dividing by 2. The mean vertical angle should agree with the first reading by 0.5 mil.

58. Declination Constant

The three types of north referred to in artillery survey are: true north, magnetic north, and grid north. For purposes of this manual the term "true north" is considered to be synonymous with astronomic and geodetic north. All points for artillery survey purposes are located with respect to grid north. To determine grid north from a magnetic reading instrument, determine the angular difference between grid north and magnetic north. The clockwise angle from grid north to magnetic north is called the declination constant. It may

also be called the *grid azimuth of magnetic north* (fig. 11).

59. When to Declinate the Aiming Circle

To determine the declination constant for each instrument and to keep it current, certain rules prescribe how often and under what circumstances the aiming circle should be declinated. These rules are as follows:

a. As a general rule, the aiming circle must be redeclinated when it is moved 25 miles or more from the area in which it was last declinated. Any appreciable move (a few miles) of the aiming circle may change the relationship of grid north and magnetic north as measured by the instrument. In some locations, a move of less than 25 miles may cause the aiming circle to have to be redeclinated.

b. The aiming circle must be redeclinated after an electrical storm or after receiving a severe shock, such as a drop from the bed of a truck to the ground. The magnetic needle is a delicately balanced mechanism, and any shock may cause a significant change in the declination constant for the instrument.

c. The aiming circle should be redeclinated every 30 days because of the annual variation resulting from the gradual movement of the magnetic field. The annual variation may cause only a slight change (0.3 mil per year at Fort

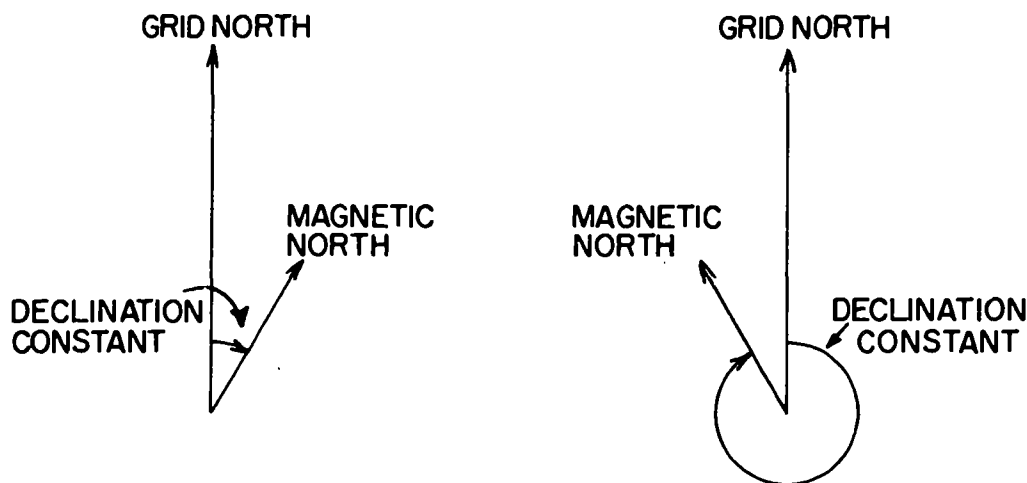


Figure 11. Schematic diagram illustrating the angular value which represents the declination constant.

Sill, Okla.), or it may be vastly significant (for other parts of the earth).

d. The aiming circle should be declinated when it is initially received and redeclinated when it is returned from ordnance repair. Variations in the declination constant due to the time of day are not significant enough to warrant a redeclination at any specific time.

60. Where to Declinate the Aiming Circle

A declination station should be established at a place convenient to the using units. It may be established by a field artillery battalion, division artillery, or target acquisition battalion. The declination station should be a station at which azimuths to two or more azimuth marks are known (at least two azimuth marks are desired but one will suffice). For best results azimuth marks should be at least 1,000 meters from the declination station (if necessary the azimuth marks may be as close as 300 meters).

a. Declination stations are established by using a transit or theodolite. The direction to the azimuth marks is determined by applying an angle measured from a known direction, by computing the azimuth (providing the coordinates of the declination station and the azimuth mark(s) are known), or by astronomic observations.

b. Declination stations should be established in an area free from magnetic attractions. The following minimum distances from common objects with magnetic attraction are prescribed:

Power lines	150 meters
Electronic equipment	150 meters
Railroad tracks	75 meters
Heavy and medium artillery, tanks	60 meters
Light artillery, trucks	40 meters
Barbed wire or helmets	10 meters

c. Any survey control point may be used as a declination station providing an azimuth is known to some distant point.

61. Procedure for Declinating the Aiming Circle at a Declination Station

When a declination station is available, the procedures in declinating the aiming circle are as follows:

a. Set up the aiming circle in the prescribed manner. Level the instrument and perform the checks outlined in paragraph 66.

b. Set the known grid direction to the azimuth mark on the scales of the instrument and, with the lower motion (nonrecording), sight on the azimuth mark.

c. Release the magnetic needle. With the upper motion (recording), center the needle through the magnetic needle magnifier.

d. Read the declination constant directly from the scales (to 0.5 mil).

e. Relevel the aiming circle; repeat b through d above. Determine a second declination constant by using a second known azimuth mark if one is available; if not available, use the same azimuth mark.

f. Compare the two declination constants determined. If they vary more than 2 mils, repeat the entire procedure. If they agree within 2 mils, determine the mean and record it to the nearest 1 mil on the notation strip of the aiming circle.

62. Procedure for Declinating the Aiming Circle When a Declination Station is not Available

In rapidly moving situations, time may not permit establishment of a declination station. Under such circumstances, declination is performed as follows:

a. Select a point on the ground that is identifiable on the map. Place the instrument over this point and prepare it for declination by leveling it and performing the checks in paragraph 66.

b. Select two distant points which can be identified on the map and scale the direction to each point from the map.

c. Use the direction scaled from the map and declinate the instrument by following the procedure in paragraph 61.

d. Compare the declination constants determined to each of the two distant points. They must agree within 10 mils.

e. If the declination constants agree within 10 mils, mean the readings and record the declination constant. If they do not agree, repeat the entire procedure.

f. Verify the declination constant determined by this method as soon as possible.

63. Determining Vertical Angle Correction

The purpose of a vertical angle correction (VAC) is to insure that the vertical angle de-

terminated with the instrument is correct. A vertical angle correction is determined at the same time that the declination constant is determined. There are two methods which may be used to determine the vertical angle correction, the comparison method and the alternate method.

a. To determine the vertical angle correction by the comparison method, the vertical angles from the declination station to the azimuth marks must be known. These vertical angles may be measured with a transit or theodolite or they may be computed from height and distance. If computed vertical angles are used, the measured vertical angles should be observed to height of instrument at the unoccupied stations. The vertical angle correction is determined by the comparison method as follows:

- (1) After determining the declination constant, verify the level of the instrument. Measure the vertical angle to each azimuth mark to which the vertical angle is known. Read and record the value to the nearest 0.5 mil.
- (2) Verify the level of the instrument and measure the vertical angle to each azimuth mark a second time. Record the value of the second angle.
- (3) Mean the vertical angles measured to each azimuth mark and compare the mean of each with the corresponding known vertical angle. Determine the differences ($\pm$). The differences determined should be within 1 mil of each other. A mean difference should be determined. This mean difference to the tenth of a mil should be written on the notation strip with the declination constant (i.e., VAC 4.0 mils).

Example:

+ 23.0 mils	= known vertical angle to azimuth mark 1
+ 21.5 mils	= mean measured vertical angle to azimuth mark 1
+ 1.5 mils	= difference
- 9.0 mils	= known vertical angle to azimuth mark 2
- 10.8 mils	= mean measured vertical angle to azimuth mark 2
+ 1.8 mils	= difference

+ 1.5 mils	= difference at azimuth mark 1
+ 1.8 mils	= difference at azimuth mark 2
+ 1.6 mils	= mean difference or vertical angle correction

b. To determine the vertical angle correction by the alternate method, two stations are established approximately 100 meters apart. The stations should be marked with a hub or some other convenient marker. It is not necessary to know the coordinates and height of the stations or the distance between them. The aiming circle is set up at one of the stations. The height of instrument is marked on a ranging pole with a pencil. The height of instrument is measured from the height of the station marker (e.g., hub) to the center of the objective lens of the telescope. The ranging pole is placed vertically over the second station. The vertical angle to the mark on the ranging pole is then measured with the aiming circle. (One edge of a card may be held coincident with the pencil mark to assist in sighting. As an arbitrary rule, such a card is usually placed so that the top edge is coincident with the mark.) The aiming circle is then moved to the second point and set up. The height of instrument at the second station is marked on the ranging pole. The pole is set up over the first station, and the vertical angle from the second station to the first station is measured. The vertical angles measured at the two stations are compared. If they are numerically equal but of opposite sign (e.g., +7.0 and -7.0), the level line checks; if not, a vertical angle correction must be determined. The correction is numerically equal to one-half of the algebraic sum of the two angles. *The algebraic sign of correction is opposite to the sign of the algebraic sum of the two angles.* For example, if one angle were +22 mils and the other were -24 mils, the vertical angle correction would be +1.0 mil. The vertical angle correction must be applied to all vertical angle measurements.

64. Measuring Grid Azimuth With the Aiming Circle

A declinated aiming circle can be used to measure grid azimuths. The procedures in measuring a grid azimuth are as follows:

- a. Set up the aiming circle (pars. 53 and 54).
- b. Using the upper motion, set the declination constant on the scales of the instrument.

- c. Release the magnetic needle and center the needle by using the lower motion.
- d. Lock the needle.
- e. Using the upper motion, turn the instrument and sight at the desired point.
- f. Read and record the measured grid azimuth as indicated on the scales of the aiming circle to the nearest 0.5 mil.

g. Repeat the procedure and determine the grid azimuth a second time. The two azimuth determinations should agree within 2 mils. If they do not agree, repeat the entire procedure. If the two determinations are within tolerances, mean the two azimuths.

- h. Record the measured grid azimuth to the nearest 0.1 mil.

Section III. CARE AND MAINTENANCE

65. Care of the Aiming Circle

Proper care of an instrument will prolong its life and insure better results to the user. Listed in *a* through *i* below are several precautions which should be observed while using the aiming circle.

- a. To protect the screw threads, do not tighten the adjusting, clamping, or leveling screws beyond a snug contact.

- b. The lenses should be cleaned only with lens tissue or a camel's-hair brush. Care should be taken not to scratch the lenses or remove the bluish coating. The bluish coating reduces the glare for the observer.

- c. The tripod legs should not be embedded in the ground with leg clamp thumbscrew firmly tightened. The thumbscrews should be left slightly loosened until the legs are embedded.

- d. The tripod head should be wiped clean of dirt and moisture and should be examined for nicks or burrs before the instrument is attached to the tripod.

- e. The magnetic needle should be locked when not in use.

- f. The azimuth knob should be positioned over the notation strip before the instrument is put in its case.

- g. Care should be taken to avoid forcing movement of the worm gears either in disengaging or engaging them. In disengaging, be sure that the gear is free before rotating the instrument. To reengage the worm gear, move the instrument back and forth slightly until the two gears mesh.

- h. The aiming circle should not be lubricated by unit personnel. All parts requiring lubrication are enclosed and should be lubricated only by ordnance instrument repair personnel. The

instrument should be checked periodically by an ordnance maintenance unit.

- i. The instrument should be kept clean and dry. Metal parts should be cleaned of grease and oil with mineral spirits paint thinner and then wiped dry. The polished surfaces should be given a thin coat of light grade aircraft instrument lubricating oil to prevent rust. Electrical parts should be cleaned with carbon tetrachloride. Rubber parts, other than electrical parts, should be cleaned with warm soapy water. After the rubber parts are dry, a coating of powdered technical talcum should be used to preserve the rubber. Canvas should be cleaned with a dry brush or by scrubbing with brush and water. Saddle soap may be used to remove oil or grease from canvas straps.

66. Maintenance Checks and Adjustments

If the maintenance checks described in *a* through *e* below (with the exception of checking the azimuth and elevation scales and associated micrometer for simultaneous zero reading) show that an adjustment is necessary, the aiming circle should be turned in to the supporting ordnance maintenance unit for repair. Checks should be performed each time prior to using the instrument. The maintenance checks are as follows:

- a. *Level Vial Check.* After the aiming circle has been leveled, rotate the instrument through 6,400 mils. If the bubbles (circular and tubular levels) do not remain centered, the instrument should be turned in for repair.

- b. *Magnetic Needle Check.* Set up and level the aiming circle. Center the south end of the magnetic needle. To test the needle for sluggishness, move an iron or steel object back and forth in front of the aiming circle. Permit the

needle to settle. If the needle does not return to center in the reticle, the instrument should be turned in for repair.

c. Tilted Reticle Check. After the aiming circle has been set up and leveled, place the crosslines on some well-defined point. Elevate and depress the telescope. If the vertical crossline moves off the point, the instrument should be turned in for repair.

d. Level Line Check. The purpose of the level line check is to determine if the vertical angles are measured correctly with the instrument. If the vertical angles are not measured correctly and there is not adequate time to turn the instrument in for repair, a vertical angle correction should be determined. The performance of this check and the procedure for determining a vertical angle correction are discussed in detail in paragraph 63.

e. Micrometer Adjustment Checks. The only adjustments that may be made by using unit personnel are the adjustments of the micrometers so that they read zero when the main scales with which they are associated read zero. The micrometer checks and adjustments should be made prior to determining the declination constant and the vertical angle correction.

(1) The azimuth micrometer is checked and adjusted as follows:

- (a) Set the zero of the azimuth scale opposite the index mark.
- (b) If the zero of the azimuth micrometer is opposite the index, no adjustment is necessary. If it is not opposite the index, loosen the screws on the end of the azimuth knob and slip the micrometer scale until the zero is opposite the index.
- (c) Hold both the azimuth knob and the micrometer scale and tighten the knob screws.
- (d) Check to insure that neither the knob nor the scale moved while tightening the screws.

(2) The elevation micrometer is checked and adjusted as follows:

- (a) Set the zero of the elevation scale opposite the index mark.
- (b) If the zero of the elevation micrometer is opposite the index, no adjustment is necessary. If it is not opposite the index, loosen the screws on the end of the elevation knob and slip the elevation micrometer scale until the zero is opposite the index.
- (c) Hold both the elevation knob and micrometer scale and tighten the knob screws.
- (d) Check to insure that neither the knob nor the scale moved while tightening the screws.

f. The telescope level vial is checked as follows:

- (1) Level the instrument.
- (2) Set the elevation scale and the elevation knob on zero.
- (3) Check the position of the telescope level bubble. It should be centered.
- (4) If the bubble is not centered, the instrument should be turned in for repair.

g. The telescope level vial is not used when measuring a vertical angle. Therefore, it is not necessary to turn in the instrument for repair solely for the adjustment of the telescope level vial.

67. Moving the Aiming Circle

When moving the instrument from station to station, a man on foot may carry the instrument, mounted on its tripod, over his shoulder. When he passes through trees or underbrush, the instrument should be cradled in both arms with the instrument head forward. When the instrument is carried in a vehicle, it should be placed in its case and protected from shock.

CHAPTER 6

TRANSIT

Section I. GENERAL

68. General

a. The transit is an instrument which may be used to obtain angular values for artillery fifth-order survey. This instrument, which is being replaced by the Wild T16 theodolite, can be used to measure both horizontal and vertical angles. Two types of transits are issued to artillery units—the 1-minute transit and the 20-second transit. The main difference between the two transits is the graduations on the horizontal scales. The least readings on the horizontal scales of a 1-minute transit and a 20-second transit are 1 minute and 20 seconds, respectively. Their vertical scales are identical; the least reading on the vertical scales is 1 minute.

b. The transit is issued with a tripod and accessories. The accessories include a hard-wood carrying case, waterproof cover, dust cap, sunshade, wrench, screwdriver, plumb bob, magnifying glass, adjusting pins, and night-illumination equipment. (The night-illumination accessories may be mounted on the instrument (fig. 12).) The transit and all accessories fit into the carrying case.

c. The principal components of the transit are the telescope, the standards, the upper (vernier) plate, the lower plate, the leveling head, and the footplate. The upper plate and all parts of the instrument which rotate with the upper plate (including the standards and the telescope) are referred to as the alidade of the transit (fig. 13).

d. The telescope, which may be either the external or the internal focusing type, magnifies an image about 18 to 25 diameters. The telescope contains a crosshair ring which has four

crosshairs. The center horizontal crosshair and the vertical crosshair are used in making pointings. The upper and lower horizontal crosshairs are stadia hairs which are used for measuring distances by stadia (TM 5-232). (The stadia hairs are not used in field artillery surveys.) The telescope is supported by trunnions resting on bearings in the standards which permit its rotation in a vertical plane. The telescope can be rotated through 360° . The telescope can be clamped in the vertical plane by means of the vertical motion clamping screw (fig. 12). When the clamping screw is tight, the telescope can be moved a small amount by means of the vertical motion tangent screw. A vertical circle is fixed on one end of the axle of the telescope and rotates with it. The vertical circle is graduated and is known as the main vertical scale. Attached to one of the standards is a vernier which is used in conjunction with the main vertical scale in reading vertical angles. Fastened beneath the telescope is a level vial, which is not used in artillery surveys.

e. Attached to the upper plate are the A-shaped standards which support the telescope. Also attached to the upper plate are verniers which are used in conjunction with the main horizontal scale to read horizontal angles. Two glass windows are provided in the upper plate. The A vernier is read through one of the glass windows. The B vernier is not read in artillery survey. Two mutually perpendicular level vials, known as plate levels, are fastened to the upper plate. One of them is parallel to the trunnions of the telescope. These plate levels indicate whether or not the plates of the instrument are level. A compass

is also mounted on the upper plate. In artillery surveys, the compass is used only to determine rough azimuths.

f. The upper and lower plates are each attached to spindles. The spindle of the upper plate fits into the hollow spindle of the lower plate. Thus, the axis of rotation of the upper plate coincides with the axis of rotation of the lower plate.

g. Attached to the upper side of the lower

plate is a horizontal circle which is graduated both clockwise and counterclockwise from 0° to 360° . This is known as the main horizontal scale. The center of the circle coincides with the axis of rotation of the spindles.

h. The spindle of the lower plate fits into the hollow center of the leveling head. The spindle of the upper plate passes through the spindle of the lower plate and the hollow center. The bottom of the hollow center is the top half of

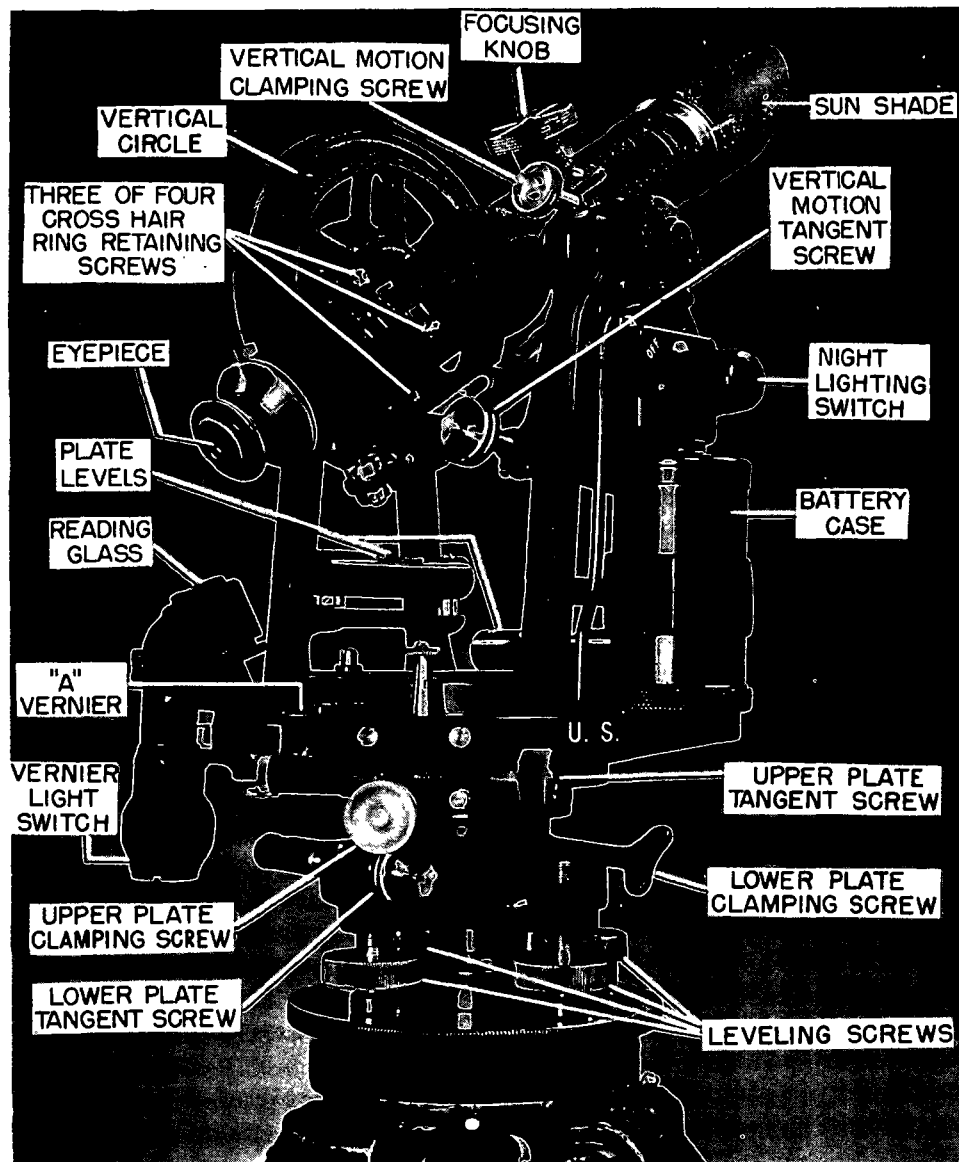


Figure 12. Transit.

a ball which pivots in a socket in a sliding plate. This plate, known as the shifting center, is mounted below the footplate. The socket of the shifting center fits through a hole in the footplate. The hole in the footplate is larger than the socket. This permits the alidade, the lower plate, and the leveling head to pivot about the ball-and-socket joint and also to slide in any direction relative to the footplate. These movements provide means of leveling

the instrument and centering it over a point. The footplate can be fastened to the head of the tripod by means of threads in the footplate and on the head of the tripod. A hook is provided at the bottom center of the leveling head to which can be fastened the cord of a plumb bob. The hook is fastened to the spindle of the upper plate.

i. Four leveling screws are fastened to arms on the leveling head. These screws are used in

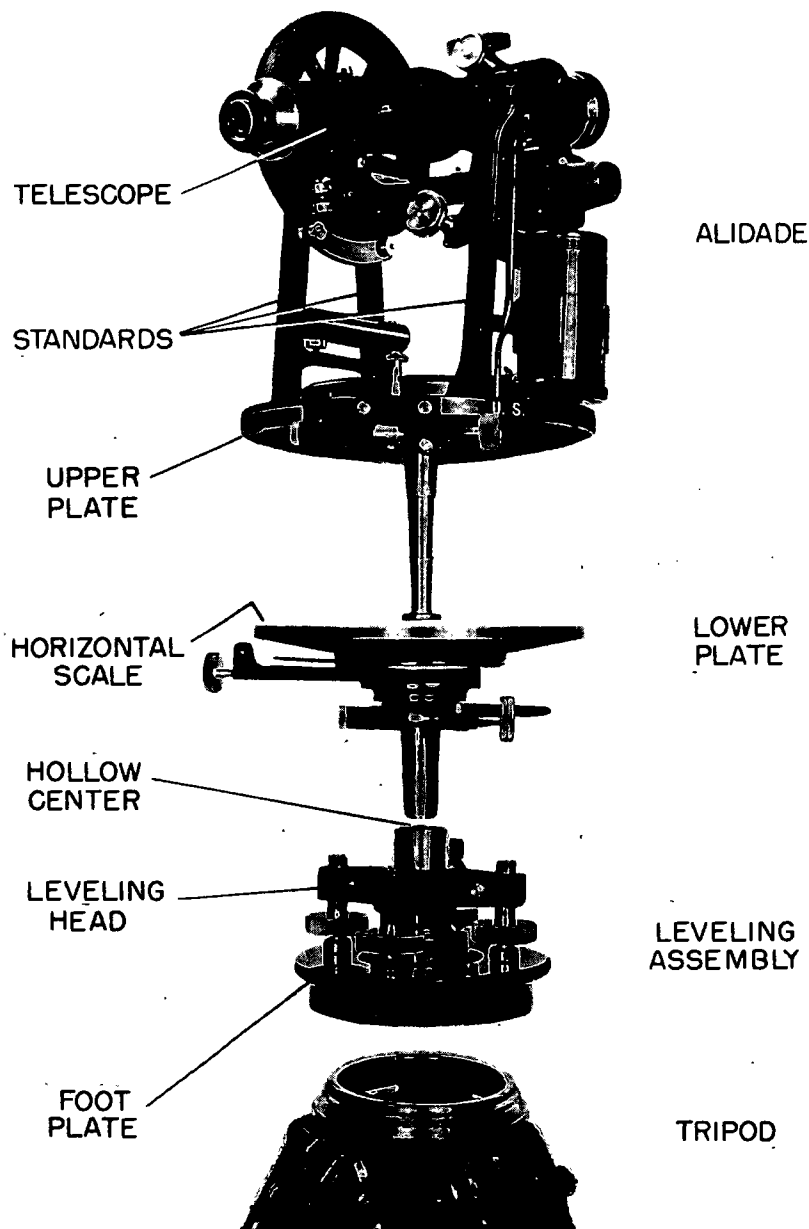


Figure 13. Transit, exploded view.

conjunction with the plate levels to level the instrument. They have shoes which bear on the footplate. When any two adjacent screws are loose, the instrument can be shifted on the footplate. When they are tight, the instrument is clamped to the footplate. Turning diametrically opposite screws in opposite directions tilts the alidade in one plane about the ball-and-socket joint.

j. The tripod head is mounted on three wooden legs. Each leg is fastened to a lug on the underside of the tripod head with a bolt and wingnut. The bottom of each leg is shod with a pointed steel shoe. An aluminum or composition cap is provided to protect the threads of the tripod head when the instrument is not in use.

k. The spindle attached to the lower plate can be clamped to the leveling head by the lower plate clamping screw. The spindle attached to the upper plate can be clamped to the spindle attached to the lower plate by means of the upper plate clamping screw. Thus, the two plates may rotate together about the leveling head (lower or nonrecording motion), or the upper plate may rotate within the lower plate (upper or recording motion). Tangent screws are provided, one for each spindle, which provide a means for rotating either spindle a small amount when the corresponding clamping screw is tight. Rotation of a plate with its clamp loose is known as fast motion. Rotation of a plate by means of its tangent screw with the plate clamped is known as slow motion. Thus, there are fast and slow upper (recording) motions and fast and slow lower (nonrecording) motions.

69. Mounting Transit on the Tripod

The tripod is set up as nearly as possible directly over the station with the legs spread at an angle that will insure stability. The tripod head should be placed approximately horizontal by adjusting the position of one or more of the legs. Remove the tripod head cover. Remove the transit from the case by grasping the cross members of the standards, being careful not to grasp the vertical circle. With one hand, place the transit on the tripod by holding the transit by the standard not containing the vertical circle and, with the other hand, loosen the lower motion clamping screw

and screw the footplate onto the tripod head. Remove the plumb bob from the transit box and suspend it from the hook under the instrument.

70. Centering Instrument Over Station

a. If the transit is not initially set up over the station, then it can be picked up as a unit with the tripod, with the legs in their same relative positions, and moved until the plumb bob hangs within 2 or 3 inches of the station mark. Push two of the tripod legs firmly into the ground so that the plumb bob, the point, and the third leg are in line and the station point is between the plumb bob and the third leg. When the third leg is then pushed into the ground, it will swing the plumb bob close to the station point. Raise or lower the plumb bob until it hangs about 1 inch over the station mark.

b. Loosen the wingnuts on the tripod legs and alter the position of the legs until the plates are approximately level and the plumb bob is over the station. Assure a firm setup by pushing the legs will into the ground. When the plumb bob is close enough to the station that any further adjustment can be made by using the shifting plate, the tripod legs are tightened in place.

c. Lower the plumb bob so that it can move freely, just above the station mark. Loosen two adjacent leveling screws so that the instrument head may be shifted on the footplate, and then move the plumb bob over the station mark. Tighten two adjacent screws to hold the transit in this position.

71. Leveling Transit

Before leveling the transit, remove the dust cap, attach the sunshade, and loosen the lower fast motion and the vertical motion clamping screw. Turn the alidade so that one of the plate levels is parallel to two diagonally opposite leveling screws (fig. 14). When one plate level is longer than the other, the long plate level is used. Grasp the heads of the leveling screws, one between the thumb and forefinger of each hand. Turn the screws so that the thumbs move either toward each other or away from each other. This tightens one screw and loosens the other. The bubble always moves in the same direction as the left thumb.

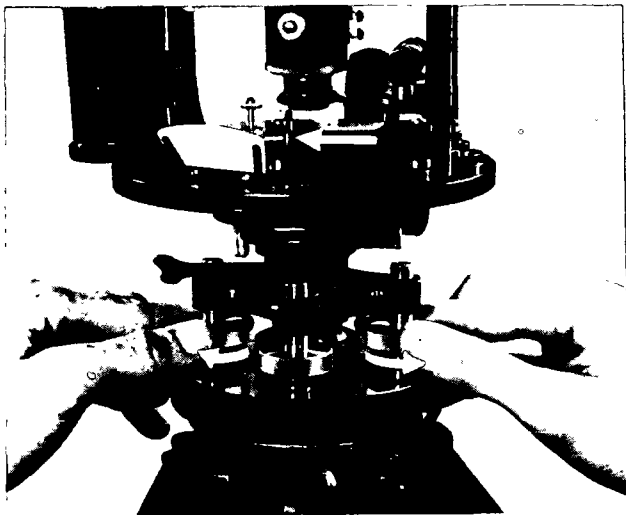


Figure 14. Leveling the transit.

After the bubble has been brought to the center of its vial, rotate the upper plate so that the plate level is parallel to the other set of diagonally opposite leveling screws and center the bubble. Return the plate level to the first position and recenter it if necessary. Return the plate level to the second position and recenter it if necessary. Repeat this procedure until the bubble is centered in both positions. Rotate the alidade through 360° . If the bubble does not move more than one graduation throughout the rotation, the transit is considered level. If the bubble moves off center more than one graduation, place the plate level parallel to the leveling screws first used but on the opposite side of the leveling head from the position in which the bubble was first centered. Move the bubble toward the center one-half of the deviation, using the leveling screws. Repeat this procedure with the plate level parallel to the other pair of diagonally opposite screws. Again rotate the plate 360° . The bubble should not move more than one graduation. If it moves more than one graduation, continue the level-

ing procedure until the bubble moves less than one graduation when the alidade is rotated through 360° . If it is impossible to level the transit by the above-mentioned procedures, the plate levels should be adjusted (par. 83).

72. Adjusting for Parallax

Before a transit (or theodolite) is used for measuring angles, the telescope must be properly focused (adjusted for parallax). The telescope is adjusted for parallax by bringing the focus of the eyepiece and the focus of the objective lens to the plane of the crosshairs (crosslines). Improper adjustment for parallax causes apparent motion of the target (point sighted on) when the eye is moved across the eyepiece. This parallax (apparent motion) introduces error in measured angles. When parallax exists, an instrument operator is unable to make consistently accurate pointings. Proper adjustment for parallax does not necessarily produce the clearest and sharpest image of a distant object. The instrument is adjusted for parallax as follows:

- a. Point the telescope toward a bright space such as the sky.
- b. Focus the eyepiece by rotating it until the crosshairs appear sharp and black.
- c. Point the telescope on some distant object and focus the objective lens by rotating the focusing knob until the image of the object is clear and sharp.
- d. Test the adjustment by moving the eye slowly across the eyepiece. If the image of the object sighted on appears to move with respect to the crosshairs, parallax is present. The focus of each lens should be changed slightly until the crosshairs are sharp and clear, the image is clear, and there is no apparent motion. The focus of each lens may have to be readjusted throughout the day, if the observer's eyes become tired.

Section II. USE OF TRANSIT

73. Scales

a. The horizontal scales of a transit (figs. 15 and 16) consist of the main scale and two verniers (A and B). Normally, only the A vernier is used in artillery surveys. The main

scale is a complete circle graduated from 0° to 360° , clockwise and counterclockwise. There are two series of numbers which label the graduations. The inner series increases from 0° to 360° in a clockwise direction; the outer

series increases in a counterclockwise direction. The inner series (clockwise) is used in artillery surveys. The main scale is attached to the lower plate and rotates only with the lower motion of the transit. The verniers are arcs, mounted edge-to-edge with, and inside of, the main scale. They are attached to the upper plate and rotate in a horizontal plane with the alidade.

b. The vertical scales differ from the horizontal scales in that the main scale is inside the vernier and rotates with the telescope, but the vernier is fixed. Furthermore, the main vertical scale is divided into quadrants of 90° each (fig. 17).

74. Reading Horizontal Scales of the 20-Second Transit

The least reading on the main horizontal scale of the 20-second transit is 15 minutes

(fig. 15). The least reading on the vernier is 20 seconds. To read an angle, first determine the value on the main scale opposite the index in the center of the vernier. If the index falls between two main scale graduations, the graduation having the smaller value (graduation to the right of the index) must be read. In figure 15, the value on the main scale is $125^\circ 45'$. Next, determine the value on the vernier. The value on the vernier is always read on that portion of the vernier to the left of the index. To determine the value on the vernier, observe along the scale in a clockwise direction from the index until a graduation on the vernier is found that coincides with a graduation on the main scale. In figure 15, this value is $05' 20''$. Finally, add the value read on the vernier to the main scale reading. The value of the angle read from the main scale and the vernier in

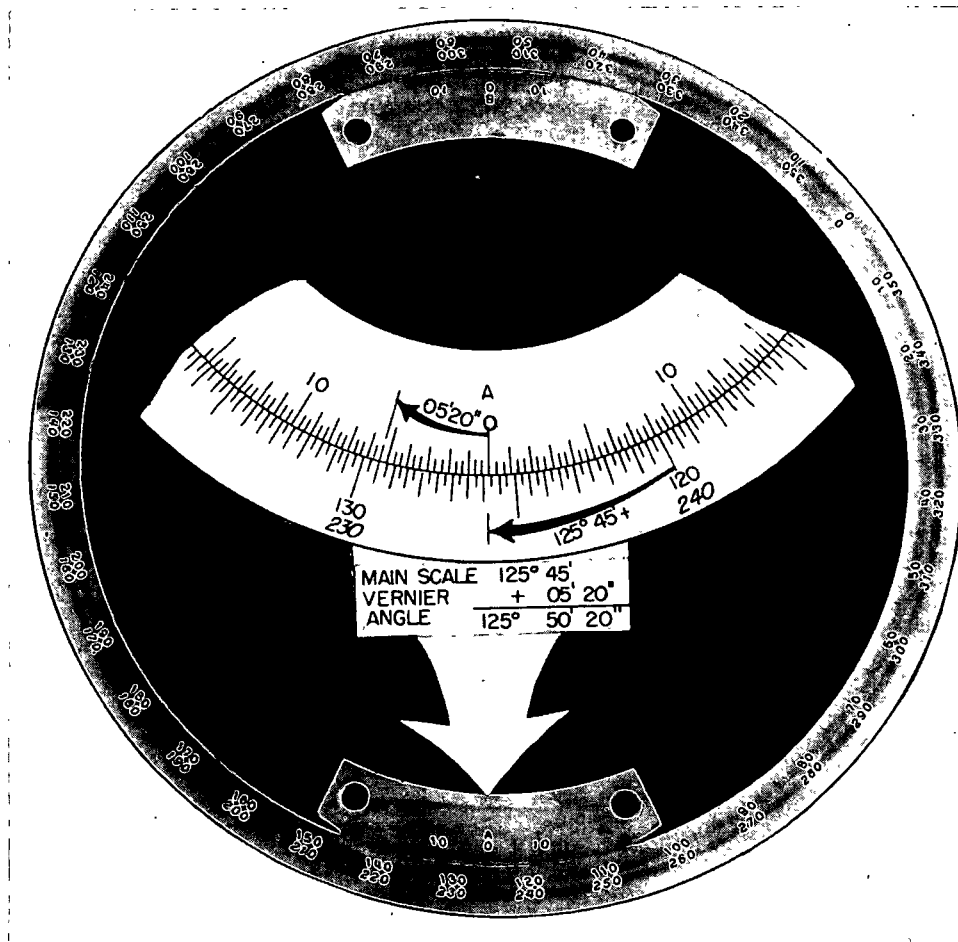


Figure 15. Horizontal scale, 20-second transit.

figure 15 is $125^{\circ} 45'$ plus $05' 20''$ or $125^{\circ} 50' 20''$.

75. Reading Vertical Scales of the 20-Second Transit

The least reading on the main vertical scale of the 20-second transit is 30 minutes. The least reading on the vernier is 1 minute. In measuring vertical angles, both sides of the vernier are used. A simple rule of thumb always designates the proper side of the vernier to use. Draw an imaginary line from the 0 on the main scale toward the 0 on the vernier. This line will point toward the side of the vernier which should be used. For example, in figure 18, the imaginary line from the main scale 0 to the vernier 0 points toward the right side of the vernier, and the right side of the vernier must be used. In this example, the main scale reading is $06^{\circ} 30'$ and the vernier

reading is $09'$. Thus, the reading on the vertical scales is $06^{\circ} 30'$ plus $09'$ or $06^{\circ} 39'$. It is easy to determine the sign of a large vertical angle by observing whether the telescope is pointing up or down. However, with vertical angles less than 1° , it is difficult to determine which way the telescope is pointing. The sign of the vertical angle can be determined by the position of the zeros on the vertical scale and vernier. If the 0 on the vertical scale is between the objective end of the telescope and the 0 on the vernier (direct or reverse), the vertical angle is plus (+). If the 0 on the vertical scale is between the telescope eyepiece and the 0 on the vernier (direct or reverse), the vertical angle is minus (-). For example, in figure 18 the 0 on the vertical scale is between the telescope eyepiece and the 0 on the vernier. Therefore, the vertical angle in figure 18 is minus and is recorded as $-06^{\circ} 39'$.

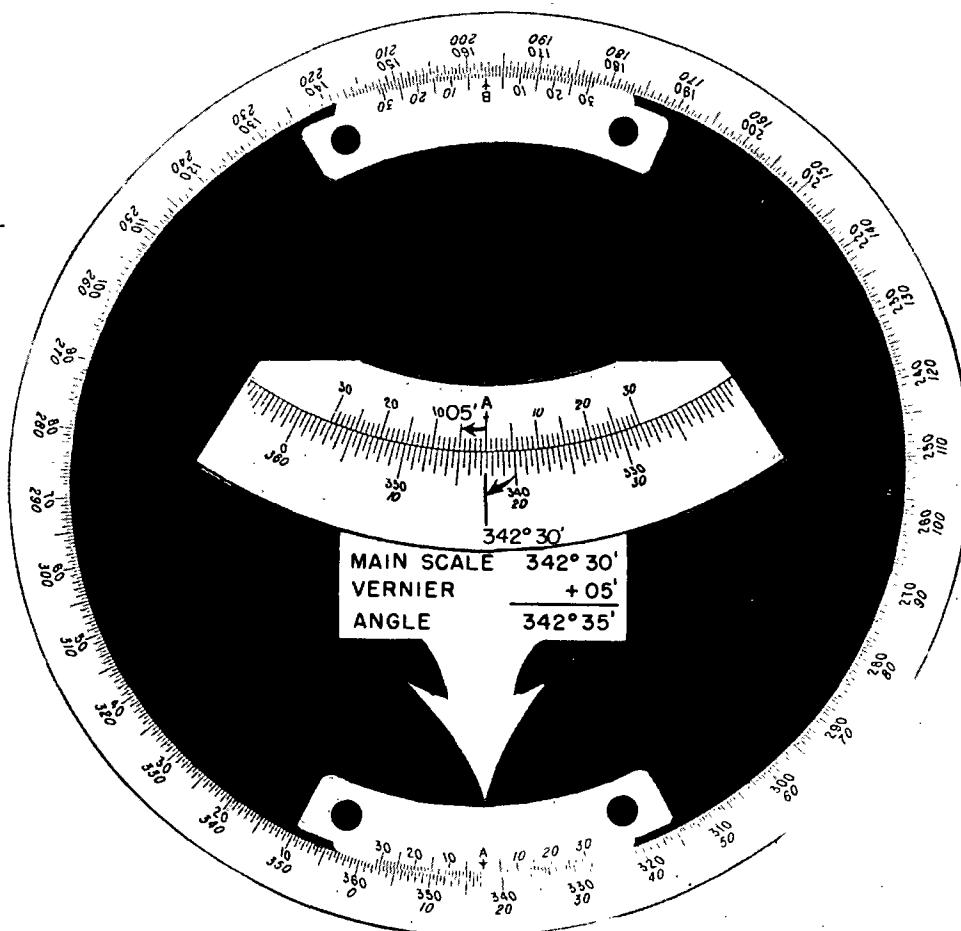


Figure 16. Horizontal scales, 1-minute transit.

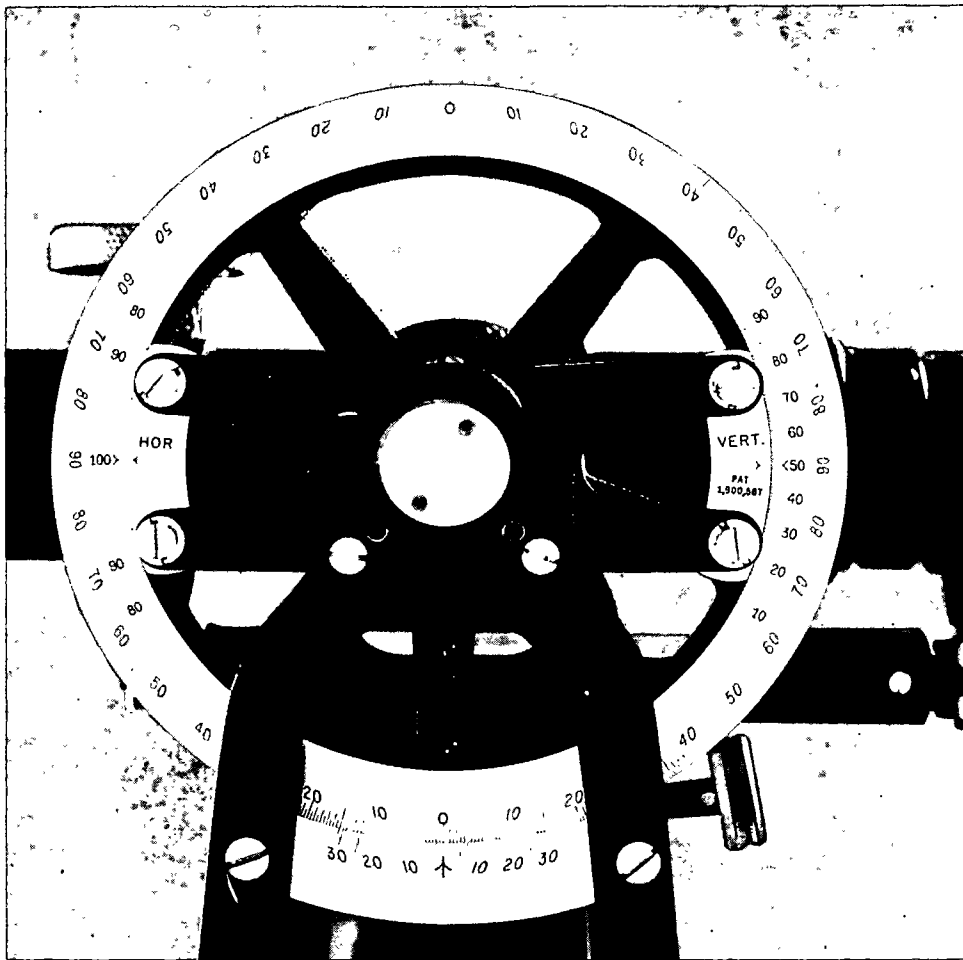
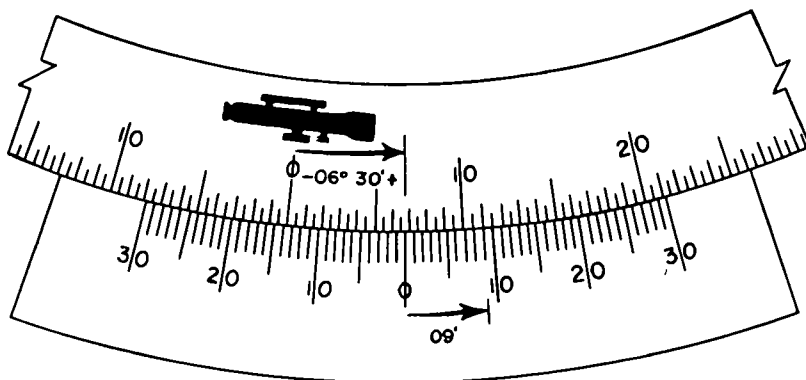


Figure 17. Vertical scales.



Main Scale	-06° 30'
Vernier	+ 09'
Angle	-06° 39'

Figure 18. Reading on vertical scales of the transit.

76. Reading Scales on the 1-Minute Transit

a. The least reading on the main horizontal scale of the 1-minute transit is 30 minutes (fig. 16). The least reading on the vernier is 1 minute. The horizontal scales of a 1-minute transit are read in a manner similar to that in which the horizontal scales of a 20-second transit are read. In figure 16, the main scale reading is $342^{\circ} 30'$ and the vernier reading is $05'$. The value of the angle read from both scales is $342^{\circ} 30'$ plus $05'$ or $342^{\circ} 35'$.

b. The vertical scales of the 1-minute transit and the 20-second transit are identical and are read in the same manner.

77. Measuring Horizontal Angles

a. With the transit set up over the station at which the angle is to be measured, adjust for parallax and set the 0 of the A vernier exactly opposite the 0 of the main horizontal scale, using the upper motions. Using the fast lower motion, point the telescope approximately at the rear station by sighting, first over the top of the telescope and then through it. Clamp the lower plate clamping screw. With the slow lower motion, place the cross hairs exactly on the station. (The final direction of movement of the cross hair should be made from right to left by rotating the tangent screw in a clockwise direction.) Unclamp the upper plate clamping screw. Rotate the alidade until the telescope is pointed approximately at the forward station by sighting, first over the top of the telescope and then through it. After clamping the upper plate, use the slow upper motion to place the cross hairs exactly on the forward station. (The final direction of movement of the crosshairs should be made from right to left by rotating the tangent screw in a clockwise direction.) Unclamp the lower motion. (*The lower motion should be unclamped at all times except for measuring an angle.*) Read the value of one measurement of the angle from the horizontal scale. Record this value.

b. The complete measurement of any horizontal angle consists of the mean of at least two separate measurements. When two separate measurements are made, one is made with the telescope direct and one with the telescope

reversed (1 D and R). One measurement of the angle is made as described in *a* above; then the telescope is plunged (rotated 180° in a vertical plane so that the focusing knob is below, rather than above, the telescope). The telescope is again pointed exactly at the rear station, using the lower motions (the upper motion is not disturbed). The telescope is then pointed exactly at the forward station, using the upper motions. The accumulated value of the two measurements of the angle is then read on the horizontal scales and recorded. In artillery fifth-order surveys, the number of separate measurements of an angle that are taken is two (1 D and R). The same number of measurements must be made with the telescope reversed that are made with the telescope direct. The direct measurements are always made first; the telescope is plunged, and then the reversed measurements are made (each measurement is accumulated on the scales). The values of the first direct and the last reversed measurement are read and recorded. The mean angle is determined by dividing the accumulated value of the measurements by the number of measurements; for example, an angle 1 D and R is meant as follows:

Direct (D)	$135^{\circ} 16' 20''$
Reverse (R)	$270^{\circ} 32' 20''$
Mean angle	$135^{\circ} 16' 10''$

When an angle is measured 1 D and R and the direct reading exceeds 180° , then the angle is meant by adding 360° to the reverse reading and dividing the sum by 2. This mean angle is considered to be the measured value of the angle. The value of the first direct measurement of an angle should be compared with the value of the mean angle. The primary purpose of this comparison is to detect errors, such as making an improper number of repetitions with the telescope in the direct or reversed positions.

c. When a transit is used to measure the angle(s) at a station, the angle closing the horizon should be measured. The angle closing the horizon is measured from the forward station of the last required angle to the rear station of the first required angle. If only one required angle is measured, the angle closing the horizon is measured from the forward station to the rear station of the required angle.

The angles about a station should be measured in a clockwise sequence. The angle closing the horizon is usually measured last. Figure 19 illustrates horizon closure. The sum of the

$$\frac{\text{Number of angles measured Including closure angle}}{\times}$$

$$\frac{\text{Least reading of transit}}{\text{Number of measurements per angle}}$$

For example, if three angles (including the angle closing the horizon), are measured one D and R, with a 1-minute transit, the sum of the angles should not vary from 360° by more than—

$$3 \times \frac{60 \text{ seconds}}{2} = 90 \text{ seconds}$$

If the sum of the angles varies from 360° by

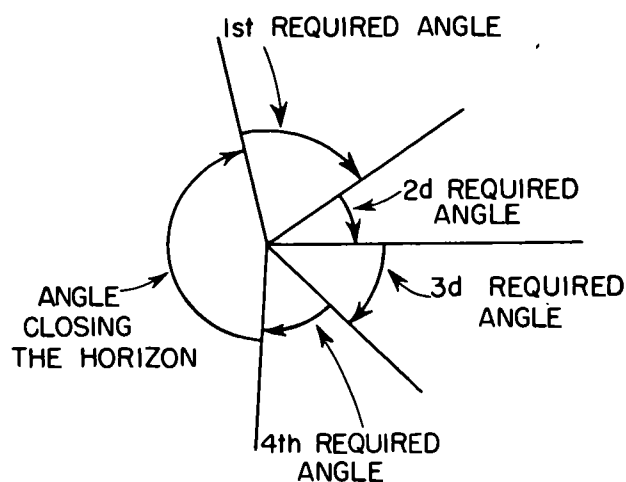
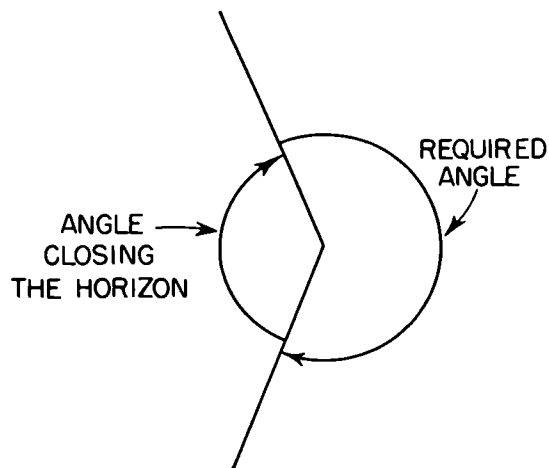


Figure 19. Horizon closure.

angles measured about a station, including the angle closing the horizon, should not vary from 360° by more than a value computed as follows:

more than the value computed as explained above, the angles must be remeasured.

d. When the angles measured about a station have been determined within the tolerance explained in c above, their mean values must be adjusted so that their sum equals 360° 00' 00". The amount by which each angle must be adjusted is determined by dividing the difference between the sum of the angles and 360° 00' 00" by the number of angles measured about the station. The quotient resulting from this division may not be a whole number. In that case, the remainder is distributed, 1 second each, among the angles having the greatest values. For example, three mean angles were determined and are adjusted as follows:

Angle 1	165° 49' 20"
Angle 2	 90° 06' 20"
Angle 3	104° 04' 00"
Sum	359° 59' 40"

In this case, the sum of the angles differed from 360° by 20". To determine the amount by which each angle is to be adjusted, divide 20" (difference between sum and 360°) by 3 (number of angles). The quotient is 06" with a remainder of 02". Distribute the remainder by adding 01" to the corrections for the 2 largest angles, thus making the corrections 06", 07", and 07". Apply the corrections to the mean angles in such a way as to make their sum equal to 360° 00' 00", as follows:

	Mean	Corrections	Adjusted
Angle 1	165° 49' 20"	(+07")	165° 49' 27"
Angle 2	90° 06' 20"	(+06")	90° 06' 26"
Angle 3	104° 04' 00"	(+07")	104° 07' 07"
Sum	359° 59' 40"		360° 00' 00"

e. The procedures discussed in a through d above apply to measurements made with both the 20-second and 1-minute transits.

78. Measuring Vertical Angles With Transit

a. The vertical angle to a point is measured from the horizontal plane passing through the axis of the telescope of the transit. To measure

a vertical angle to a point with the transit, set the transit over the station at which the angle is to be read. With the telescope in the direct position, place the crosshairs on the point at HI. (The final direction of rotation of the vertical motion tangent screw should be in a clockwise direction.) Read the measurement of the vertical angle on the main vertical scale and the vernier. Plunge the telescope and again place the crosshairs on the point. Read the measurement of the vertical angle on the vertical scales. Determine the mean vertical angle by dividing the scale reading by 2. This is the *mean angle* and is considered to be the measured value of the angle.

b. When measuring a vertical angle in conjunction with the measurement of a horizontal angle, read the first value of the measurement of the vertical angle immediately before reading the value of the first (direct) measurement of the horizontal angle. Read the value of the second (reversed) measurement of the vertical angle immediately before reading the value of the last (reversed) measurement of the horizontal angle. The vertical angle is always measured in conjunction with the pointings on

the forward station of a horizontal angle. (If the vertical angle is required to the rear station of the first angle, it is measured in conjunction with the pointings on the forward station of the angle closing the horizon.) After the crosshairs have been placed on the forward station, raise (or lower) the telescope until the horizontal crosshair is pointed at the HI. Unclamp the lower motion. Rotate the transit so that the vertical scale can be read conveniently. Read the vertical scales. Rotate the transit so that the horizontal scales can be read conveniently. Read the horizontal scales. (Reading the vertical scales first permits the telescope to be elevated to facilitate reading the horizontal scales.)

c. Figure 20 is a sample record of horizontal and vertical circle readings.

79. Care of Transit

The transit is a delicate instrument; care must be taken not to drop or bump it against any object. In moving the instrument from station to station, a man on foot may carry the instrument, mounted on its tripod, over his shoulder (fig. 21). When he passes through

Station	Horizontal Δ					Vertical Δ		II
	T	R	0	I	II	0	I	
AZMK	D	1	120	15	00	+1	12	
BNSCP	R	2	240	30	20	+1	13	
TSI	MN	Δ	120	15	10			
	ADJ	Δ	120	15	15	+1	12	30
TSI	D	1	239	45	00			
BNSCP	R	2	119	29	20			
AZMK	MN	Δ	239	44	40			
	ADJ	Δ	239	44	45			

Figure 20. Recording horizontal and vertical circle readings.

trees or underbrush, he should carry it under one arm, with the hand of his other arm on the head of the tripod or the footplate of the transit (fig. 22). In either case, the upper motion should be clamped and the lower motion left unclamped. The telescope should be clamped with the telescope pointing upward. When the instrument is carried in a vehicle, it should be placed in its case. Before placing the transit in its case, the transit operator should verify that the shifting center is in the center of the footplate and that the leveling screws are approximately at the same height. The upper motion should be clamped; the lower motion should not. The vertical motion should be clamped. *The case should be held on the lap of the operator or cushioned from shock in some other way.*

80. Cleaning Transit

The transit must be kept clean and dry. During use, as necessary, and after use, the instrument should be cleaned as follows:

- a. Painted surfaces should be wiped with a clean cloth.
- b. The exterior of the vernier windows should be cleaned with a camel's-hair brush or wiped with a clean cloth.
- c. The exterior of the eyepiece and the objective lens should first be brushed with a camel's-hair brush to remove dust and then wiped with lens tissue to remove moisture.



Figure 21. Carrying transit on the shoulder.

Care must be taken not to scratch the lenses and the coating on the lenses.

d. The vertical circle and vertical circle vernier should be brushed with a camel's-hair brush or wiped with lens tissue. *Lens tissue should be wiped across (perpendicular to) the graduations to avoid removal of the blacking.*

e. The leveling screws should be cleaned one at a time. Run the screw which is diagonally opposite the screw to be cleaned all the way up. At the same time, run the screw to be cleaned all the way down. The screw should be cleaned with a clean cloth. A string may be pulled through the grooves to aid in removing dust.

f. The upper surface of the footplate should be wiped with a clean cloth. *This surface must be kept clean at all times.*

81. Repair of Transit

Adjustment (except as explained in pars. 82-87) and repair of the transit must be performed by qualified instrument repair personnel. Artillery units should turn transits in to the engineer unit which is responsible for providing maintenance service for necessary adjustment and repair.

82. Adjustment of Transit

a. The transit must be kept in good adjustment to obtain accurate results. There are five tests and adjustments of the transit that the



Figure 22. Carrying transit under one arm.

artillery surveyor must be capable of performing. These tests and adjustments are described in paragraphs 83 through 87.

b. All tests and adjustments of the transit are made with the instrument mounted on its tripod and set up in the shade. The five tests of the instrument should be made periodically, in the sequence in which they are discussed in paragraphs 83 through 87. *When one of the tests indicates that an adjustment is necessary, this adjustment must be made and all previous tests must be repeated before proceeding with the next test.*

83. Adjustment of Plate Levels

a. *Purpose.* The purpose of the adjustment of the plate level is to make the level vials parallel to the upper plate.

b. *Test.*

- (1) Using the leveling screws, bring the bubbles of both plate levels to the centers of their vials.
- (2) Turn the transit through 180° of azimuth. If these levels are correctly adjusted, the bubbles will then come to rest centered in their vials.

c. *Adjustment.* When the bubble of either plate level comes to rest off center in the test, the bubble should be moved halfway back to center by turning the leveling screws, and then it should be centered by turning the capstan nut at either end of the level tube.

d. *Frequency of Test and Adjustment.* The test of the plate levels should be made every time the instrument is set up for use. When an error in the adjustment of either plate level is indicated, it is not always necessary to make the adjustment, because the operation of bringing the bubble halfway back to center by turning the leveling screws makes the vertical axis of the transit vertical. The adjustment must be made, however, before other tests and adjustments of the instrument. For artillery survey needs, only the long bubble need be in adjustment; however, in case of damage to the long bubble, the short bubble should also be in adjustment.

84. Verticality Adjustment of Vertical Crosshair

a. *Purpose.* The purpose of the verticality adjustment is to make the vertical crosshair lie

in a plane perpendicular to the horizontal axis of the telescope.

b. *Test.*

- (1) Select a stable, well-defined point that is at least 100 meters from the transit. Center the vertical crosshair on this selected point.
- (2) With the elevation tangent screw, elevate and depress the telescope. If this adjustment is correct, the point will appear to move up and down on the vertical crosshair.

c. *Adjustment.*

- (1) If the point moves away from the vertical crosshair, loosen the screws holding the crosshairs and rotate the reticle by lightly tapping two opposite screws.
- (2) Sight on the point again and if the vertical crosshair does not follow the point throughout its entire length, rotate the ring again.
- (3) Repeat this process until the condition is corrected.

85. Collimation Adjustment of Vertical Crosshair

a. *Purpose.* The purpose of the collimation adjustment of the vertical crosshair is to make the line of sight (as defined by the vertical crosshair) perpendicular to the horizontal axis of the telescope.

b. *Test.*

- (1) Point the telescope at a point about 100 meters distant and set a stake at that point. Clamp both the upper and the lower motions. Mark the stake with the letter A exactly on the line of sight.
- (2) Plunge the telescope and set a second stake on the line of sight at a distance from the instrument approximately equal to that of the first stake. Mark the second stake with the letter B exactly on the line of sight. Label this mark B. *(The two stakes and the instrument should be as nearly in a common horizontal plane as possible.)*
- (3) Rotate the alidade, using the lower motions, until the crosshairs are again on mark A.

- (4) Plunge the telescope. If the instrument is in adjustment, the line of sight will fall on mark B.

c. Adjustment.

- (1) If the line of sight does not fall on mark B, place a mark C exactly on the line of sight. Normally, mark C will fall on the stake on which mark B was placed. If it does not, a card may be attached to the stake and mark C is placed on the card.
- (2) The point midway between marks B and C is the extension of the straight line from mark A through the instrument. Place mark D at the point midway between B and C. Place a mark E at the point midway between C and D.
- (3) With the telescope pointed at mark C, adjust the crosshairs until they are exactly on mark E by loosening the crosshair ring-retaining screw on one side of the telescope tube and tightening the opposite screw. To move the crosshair to the left, loosen the screw on the left side; to move it to the right, loosen the screw on the right side.
- (4) Rotate the alidade until the vertical crosshair falls on mark D.
- (5) Plunge the telescope. The vertical crosshair should fall on mark A. If it does not, the adjustment must be repeated.

86. Collimation of Horizontal Crosshair

a. Purpose. The purpose of the collimation of the horizontal crosshair is to make the instrument read the same value for the vertical angle to a point, with the transit direct and with the transit reversed.

b. Test.

- (1) Select a stable, well-defined point at least 100 meters from the transit at any vertical angle that is convenient for observing.
- (2) *For this test, the leveling of the transit is critical, so level the instrument as accurately as possible.*
- (3) Make the vertical angle readings for direct and reverse pointings to the

selected point. If these two vertical angle readings are of the same value, the collimation adjustment of the horizontal crosshair is correct.

c. Adjustment.

- (1) When the two vertical angle readings differ, adjust the position of the horizontal crosshair. For this adjustment, turn the crosshair retaining ring screws on the top and bottom of the telescope. Loosen one of these adjusting screws and tighten the other one. Tightening the uppermost adjusting screw will cause the horizontal crosshair to move down in the telescope.
- (2) With the telescope in either the direct or reverse position, set the vertical circle to read the mean of the two vertical angle values read in *b* (3) above. Then, move the horizontal crosshair ((1) above) to where it bisects the selected point (*b* above).
- (3) If while adjusting the position of the horizontal crosshair the crosshair moves out of the center of the telescope, the instrument should be turned in for adjustment of the vertical vernier.

87. Adjustment of Height of Standards

a. Purpose. The purpose of the height of standards adjustment is to make the horizontal axis of the telescope perpendicular to the vertical axis of the spindle.

b. Test.

- (1) With the telescope in the direct position, point at some well-defined, elevated object, such as the point of a church steeple. The image of the point sighted on must be as narrow as the width of the crosshairs. The vertical angle to the point sighted on should be at least 30°. Clamp both the upper and lower motions.
- (2) Depress the telescope and set a stake in the ground alined with the line of sight. Place a mark on the stake exactly where it is in the line of sight, and label this mark A.

- (3) Rotate the alidade 180° , using the lower motions; plunge the telescope; and again point at the elevated point.
- (4) Depress the telescope. If the line of sight is on mark A, the height of standards adjustment is correct.

c. Adjustment.

- (1) If the line of sight does not fall exactly on mark A, move the telescope until the crosshairs are on point A.
- (2) Elevate the telescope so that the hori-

zontal crosshair passes through the elevated point.

- (3) Move the crosshairs halfway to the elevated point by using the capstan nuts on the movable standard. (An adjusting pin is used to turn a capstan nut.)
- (4) Move the crosshair to the elevated point by using the lower motions. The crosshairs should fall on point A when the telescope is depressed. If it does not, the test and adjustment must be repeated.

CHAPTER 7

THEODOLITE, WILD T16

Section I. GENERAL

88. General

a. The Wild T16 theodolite (fig. 23) is used to obtain angular values for artillery fifth-order survey. Both horizontal and vertical angles can be measured with the theodolite. The T16 theodolite is a compact, lightweight, dustproof, optical-reading, direction-type instrument with a repeater clamp for measuring horizontal angles. The scales, graduated in mils, are readable directly to 0.2 mil and by estimation to the nearest 0.1 mil, and may be illuminated by sunlight or artificial light.

b. The T16 theodolite is issued with the following accessories: canvas accessory kit, compass, eyepiece prisms, sun filters, sunshade, two jewelers' screwdrivers, two adjusting pins, camel's-hair brush, lubricant, plastic instrument head cover, two operation and maintenance service manuals, battery case with lighting devices and three spare bulbs, and universal tripod with plumb bob, plug-in sleeve, and tripod key in leather pouch attached to tripod.

c. The carrying case for the T16 theodolite consists of a base plate and a steel, dome-shaped hood. When in the base, the instrument rests on two supports by means of two bolts and is fixed to the supports with two locking devices. A desiccant is in the base of the container. A wooden padded box is also furnished for transporting the theodolite in its case.

d. The tribrach is that part of the theodolite which contains the three leveling screws and the circular level. The leveling screws are completely enclosed and dustproof. The tribrach is detachable. A locking device holds the instrument and tribrach together.

e. The theodolite has a plate level and a ver-

tical circle level (split bubble) in addition to the circular level on the tribrach. The plate level is located between the two standards of the instrument. The vertical circle level is completely built in, adjacent to the vertical circle. A tangent screw is used to bring the ends of this bubble into coincidence.

f. An optical plumb system is provided on the theodolite for accurate centering over the station. The system is located in the revolving part (alidade) of the instrument.

g. The horizontal clamp and the horizontal tangent screw for moving the theodolite in azimuth are located adjacent to each other on the lower portion of the alidade. The vertical clamp is located on the standard opposite the vertical circle; the vertical tangent screw is on the lower portion of the same standard. The horizontal circle clamp, which fastens the horizontal circle to the alidade, is located on the front of the horizontal circle casting.

h. The 28-power telescope of the T16 theodolite is reversible. The crosslines are focused by turning the eyepiece; the image, by turning the focusing ring. Two horizontal pull-action screws are provided for correcting the collimation error. Objects viewed through the telescope are inverted.

i. An exterior tilting mirror illuminates both the horizontal and vertical circles. The horizontal circle is below the vertical circle, as it is viewed through the reading microscope.

j. An electric illumination device is issued with the T16 theodolite. In the lower housing of the theodolite is a socket to receive a plug from the battery case. A second socket in the alidade is connected to the first by an internal

sliding connection. In the second socket a plug-in is placed, the other end of which has a lamp to replace the mirror. When the current is on, this lamp illuminates both circles, both levels, and the telescope reticle. A rheostat is provided on the battery case for adjusting the amount of light. Crosslines illumination is adjusted through the use of the illuminating mirror for telescope diaphragm.

k. Standard equipment includes diagonal eyepieces for both the telescope and the circle-reading microscope. Sun filters are provided for the telescope eyepiece.

l. A circular compass is issued as an accessory item for the T16 theodolite. It is mounted in the yoke provided on the right standard. The compass is used only to check azimuth roughly, to orient the sketch in the field notes, or as a means of assuming direction. To prevent breakage of the cover glass, always place the compass with the dial down in the pocket of the accessory case.

m. The Wild universal tripod is issued with the theodolite. This model has sliding legs. The overall length of the closed tripod is 3 feet; the extended length is 5.2 feet. A leather pouch

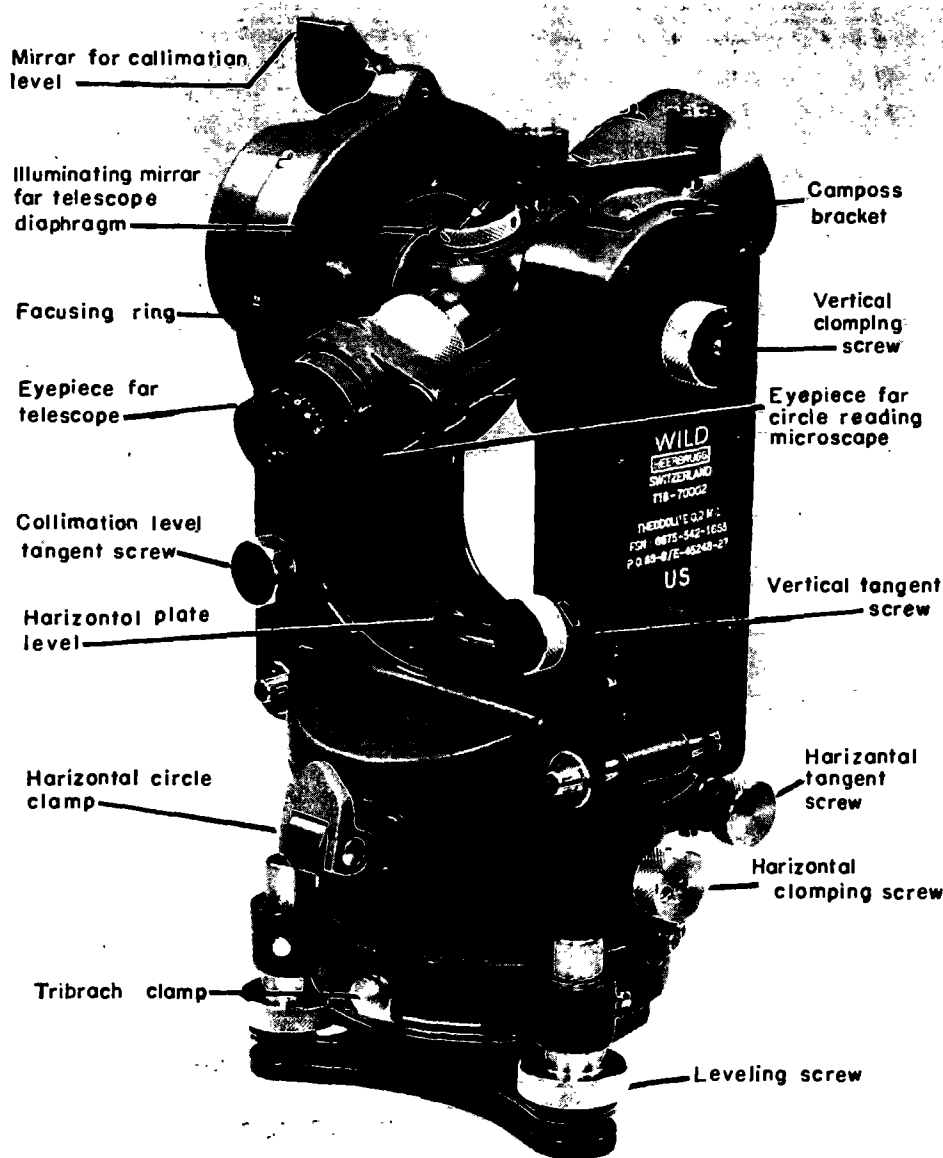


Figure 23. Wild T16 theodolite.

attached to the tripod contains a plumb bob with a plug-in sleeve and key for the tripod legs.

89. Setting up the Tripod

a. Upend the tripod and place the tripod head on the toe of the shoe.

b. Loosen the restraining strap and secure the strap around one tripod leg.

c. Hold the tripod in the erect position and test the adjustment of each tripod leg by elevating it to about 90° and then releasing it. If properly adjusted, the leg should fall to about 45° and stop. If not, the tripod leg should be adjusted by tightening or loosening the bolt.

d. With one tripod leg pointed in the direction of observation, approximately center the tripod and embed the tripod legs lightly into the ground. The head of the tripod should be about shirt pocket height.

e. Center the fixing screw in the head of the tripod and insert the plumb bob. Center the tripod over the station.

f. Check the tripod head for approximate level by sighting against the horizon.

g. Firmly embed the tripod legs.

h. Remove the tripod head cover and secure it to the tripod leg.

90. Removing the Theodolite from its Case

a. Loosen the strap on the case and unclamp the latches simultaneously by exerting pressure outward.

b. Lift the dome-shaped cover directly off the instrument and set it to one side.

c. Place the fingers under the right and left retaining clamps on the base of the case and apply pressure until the instrument releases.

d. With the right hand, securely grasp the right standard (the one with Wild inscribed on it) and lift the theodolite off the base.

e. Place left hand under the theodolite and fasten the instrument to the tripod, using the fixing screw.

f. While the theodolite is in use, the dome-shaped cover should be replaced on the base of the case.

91. Plumbing the Theodolite

a. Carefully move the instrument around the

tripod until the point of the plumb bob is centered exactly over the station.

b. Tighten the instrument to the tripod head, making sure that the plumb bob point stays centered over the station.

c. Use the optical plumb for final centering of the theodolite over the station.

d. Do not attempt to use the plumb bob when the wind is blowing. Use the optical plumb.

92. Leveling the Theodolite

a. Bring the circular level bubble to rough center by turning the three leveling screws.

b. Loosen the horizontal clamp. Turn the instrument until the plate level is parallel to any two of the three leveling screws.

c. Center the plate bubble by using these screws, turning both in toward the center of the instrument or turning both out from the center. The bubble will follow the movement of the left thumb.

d. Turn the instrument 1,600 mils. Place one end of the plate level over the third leveling screw. Using this leveling screw, bring the bubble to center.

e. Return the instrument to the first position; center the bubble if necessary.

f. Turn the instrument 3,200 mils. If the bubble is in the center of the level vial, turn the instrument 6,400 mils. The bubble should remain centered; if it does the instrument is level.

g. Check the optical plumb to insure that the instrument is still over the station. If not, center over station and repeat the leveling process.

h. If the bubble is not centered when turned 3,200 mils from the first position (f above), the level vial is out of adjustment. To adjust, move the bubble halfway back to the center of the level vial, using the same leveling screws used in the first position. Rotate the instrument 1,600 mils. Move the bubble halfway back to the center of the level vial, using the one remaining leveling screw. The instrument is now level, and the bubble will come to rest in its vial at the same offcenter position for any direction in which the instrument is pointed. The level vial should be adjusted as soon as time permits.

93. Illuminating the Circle

To illuminate the circle, open the illumination mirror and adjust the light so that both the horizontal and vertical circles are uniformly illuminated when viewed through the circle-reading microscope.

94. Focus To Eliminate Parallax

Parallax is eliminated by pointing the telescope toward the sky or any other neutral background and turning the knob on the telescope eyepiece until the crosslines are very sharp, fine black lines. In doing this, the observer should be very careful to focus his eye on the crosslines and not the sky. Next, point the instrument toward a rod or other sharply defined object and, still focusing the eye on the crosslines, bring the object into a sharp, clear image by turning the focusing ring on the telescope. Use the horizontal tangent screw to exactly center the vertical crossline on the object. To check for elimination of all parallax, move the eye horizontally back and forth across

the eyepiece. If the parallax has been eliminated, the crossline will remain fixed on the image. If some parallax still remains, the crossline will appear to jump back and forth horizontally across the object. To correct any remaining parallax, the eyepiece should be changed slightly to bring the crossline to a sharper focus, and the telescope refocused accordingly. This procedure should be repeated until the test shows no remaining parallax.

95. Taking Down the Theodolite

To take down the theodolite—

- Place the telescope straight up and tighten the vertical clamping screw.
- Turn each leveling screw to the same height.
- Loosen the central fixing screw and clamp the instrument in its carrying case.
- Tighten the horizontal clamping screw.
- Clamp the dome-shaped hood in place.
- Replace the tripod head protector and strap the tripod legs together.

Section II. USE OF THEODOLITE

96. Reading Horizontal and Vertical Circles

When the circles are viewed through the circle reading microscope (fig. 24), the vertical circle (marked "V") appears above the horizontal circle (marked "Az"). Both circles are graduated from 0 to 6,400 mils with a major graduation each 10 mils. Unit mils and tenths are viewed on an auxiliary scale graduated each 0.2 mil from 0 to 10 mils. Circle readings are estimated to the nearest 0.1 mil. The auxiliary scale is read at the index line which appears superimposed over the auxiliary scale.

97. Setting the Horizontal Circle

All measurements with the theodolite should be started from an initial reading on the horizontal circle of 1.0 mil. For practical purposes this precludes working with a mean of the direct and reverse (D/R) pointings on a starting station of less than 0 mil. To set this value on the circle, release the repeater clamp (horizontal clamp) and turn the instrument until the major graduation 0 appears on the horizontal circle. Clamp the repeater clamp and set

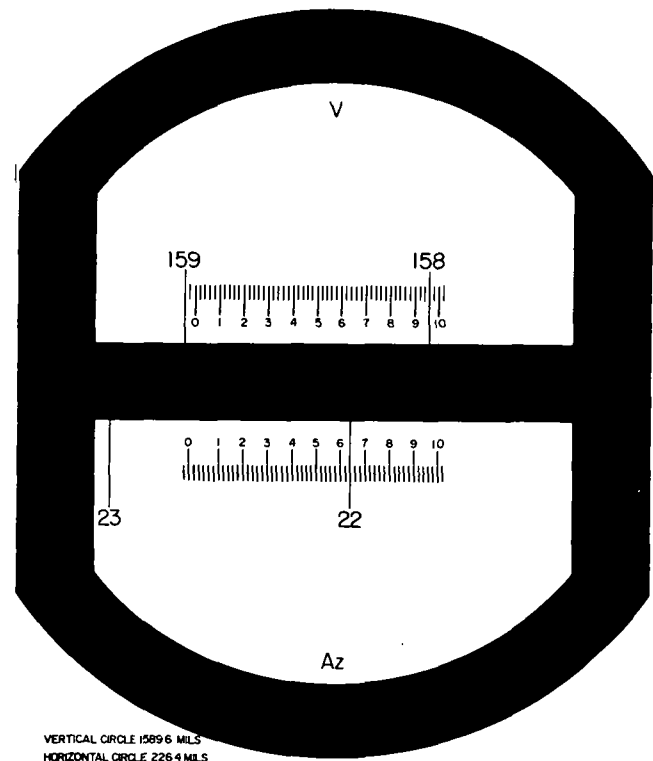


Figure 24. Scale images viewed through the circle-reading microscope.

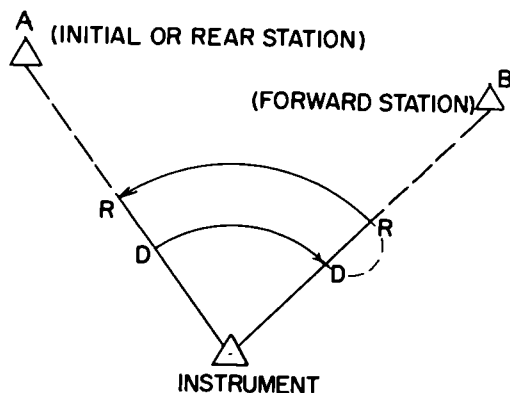


Figure 25. Determining the horizontal angle between stations A and B.

the index line directly over 1.0 mil on the auxiliary scale with the tangent screw. Engage the repeater clamp by folding it downward. The horizontal circle is now attached to the turning part of the instrument; the reading of 1.0 mil remains on the circle regardless of the direction in which the instrument is pointed.

98. Measuring Horizontal and Vertical Angles

In artillery survey, the theodolite is used as a direction instrument. The repeater clamp is used only to set the horizontal circle with the

initial circle setting on the starting point (par. 97). The size of the horizontal angle is obtained by determining the difference between the mean pointing on one station and the mean pointing on another station. The mean pointing is determined from the direct and reverse circle readings on the same point (fig. 25).

a. Set 1.0 mil on the horizontal circle. With the repeater clamp down and the horizontal clamp loose, point the telescope in the direction of station A by sighting first through the peep sight and then through the telescope. When approximately aligned on the station, clamp the horizontal clamp and refine the pointing with the slow motion tangent screw. View the circle again to insure that the reading is still 1.0 mil. This establishes the direction of station A as 1.0 mil with respect to the horizontal circle. Record in the field notes (fig. 26) the value of the direct reading on station A. Release the repeater clamp (up); this causes the circle to detach itself from the moving part of the theodolite. Release the horizontal clamp. Point the telescope on station B as above, level the vertical level bubble, and read and record the circle values—horizontal circle reading is 229.3 mils; vertical circle reading is 1598.5 mils (figs. 25 and 26).

b. Release the vertical motion clamp and plunge the telescope. Release the horizontal

STATION	T	HORIZONTAL X MILS	MEAN	VERTICAL READING	VERTICAL X
A	D	0001.0			
	R	3201.0	0001.0		
INST	MN	(228.4)			(+1.4)
B	D	229.3		1598.5	+1.5
	R	3429.4	229.4	4801.4	+1.4

Figure 26. Field notes for recording measurement of angle between stations A and B.

clamp and sight again on station B, with the telescope in the reverse position. Make pointings as above, level the vertical circle bubble, read the circles and record the values. In figure 26, the values recorded are a horizontal reading of 3429.4 and a vertical reading of 4801.4. Observe station A with the telescope still reversed and read the horizontal circle and record the value. The value recorded for the horizontal circle reading is 3201.1 mils.

c. The field notes now reflect a direct and a reverse pointing at both station A and station B. To determine the size of the angle between A and B, the mean of the pointings on A must be determined and compared with the mean of the pointings on B. This is done by mentally subtracting 3,200 mils from the reverse reading (or adding 3,200 mils to it) and meaning the direct reading with the reverse reading. The results are entered in the field notes under the

appropriate column. The mean angle is the difference between the mean pointings. In figure 26, the mean pointing on station A is 0001.0; on station B, 229.4. Therefore, the mean angle is 228.4 mils.

d. The vertical circles of the theodolite reflect readings of 0 mil at the zenith, 1,600 mils horizontal direct, 3,200 mils straight down, and 4,800 mils horizontal reversed. Hence, the values read from the vertical circles are not vertical angles. The circle readings must be converted to vertical angles (fig. 27).

e. In the field notes in figure 26, the direct reading on station B resulted in a vertical reading of 1598.5 mils or +1.5 mils; and, with the telescope reversed, the circle reading was 4801.4 mils or +1.4 mils. Hence, the mean vertical angle from the instrument to station B is +1.4 mils.

f. The telescope should be plunged to the

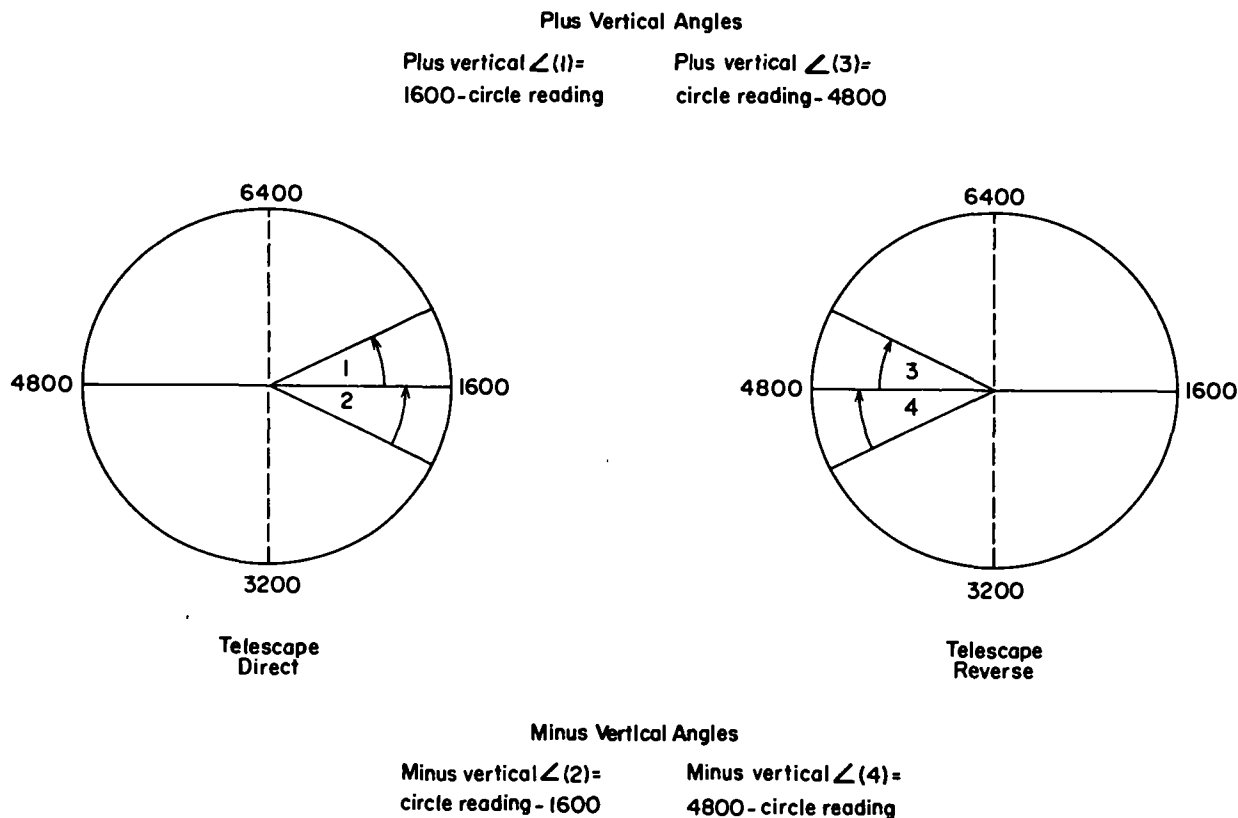


Figure 27. Vertical angles from circle readings.

direct position, after the reverse pointing on the initial station. A direct pointing should be made on the initial station with repeater clamp released (up). Although not a part of this

angle measurement, the instrument will be approximately zeroed, and time will be saved in setting the initial circle setting for the next angle measurement.

Section III. CARE AND MAINTENANCE

99. Care of Theodolite

The T16 theodolite is a delicate instrument. Care must be taken not to drop or bump it against any object. If the instrument gets wet, remove outside moisture, and as soon as possible place instrument in a warm room or tent. In moving the instrument from station to station, a man on foot may carry the instrument, mounted on its tripod, under one arm, with the hand of the other arm under the tribrach of the instrument. All motions should be clamped with the telescope pointed upward. When the theodolite is carried over rough terrain, the instrument should be transported in its carrying case. When transported in a vehicle, the theodolite should be in the dome-shaped carrying case, and the case should be in the padded box. For short distances, the carrying case may be carried in an upright position on the lap of the instrument operator.

100. Cleaning the Theodolite

The theodolite must be kept clean and dry. During use, as necessary, and after use, the instrument should be cleaned as follows:

a. Painted surfaces should be wiped with a clean cloth.

b. The exterior of the eyepieces and the objective lens of the telescope should first be brushed with a camel's-hair brush to remove dust and then wiped with lens tissue to remove moisture. *Care must be taken not to scratch the lenses or the coating on the lenses.*

c. The tripod should be kept clean, and moving parts should be oiled lightly.

101. Repair of Theodolite

Adjustment (except as explained in pars. 102-107) and repair of the theodolite must be performed by qualified *instrument repair personnel*. Artillery units should turn theodolites in for necessary adjustment and repair to the engineer unit which is responsible for providing maintenance service. TM 5-6675-200-15,

Operator, Organizational, Field, and Depot Maintenance Manual, outlines the echelons of maintenance.

102. Adjustment of Theodolite

a. The theodolite must be kept in correct adjustment if accurate results are to be obtained. There are four tests and adjustments of the theodolite that should be made periodically by the instrument operators. The adjustments are performed in the sequence in which they are discussed in paragraphs 103 through 107. When any test indicates that an adjustment is necessary, this adjustment should be made and tested for correctness before proceeding with the next test.

b. The four tests and adjustments of the theodolite are made while the instrument is mounted on its tripod. For these tests and adjustments, the instrument should be set up in the shade, on firm ground, with the head of the tripod as nearly level as possible. The theodolite should be protected from the wind.

c. An adjusted instrument will hold an adjustment for a long time, if handled properly. However, excessive movement of the adjusting screws will cause them to become worn, and the instrument will not hold an adjustment.

103. Plate Level Adjustment

a. The purpose of the plate level adjustment is to make the vertical axis of the theodolite truly vertical when the bubble of the plate level is centered.

b. To test the horizontal level, place the horizontal level parallel to two of the three leveling screws and center the bubble. Rotate the instrument 1,600 mils and place one end of the bubble over the third leveling screw. Level the bubble using only the third leveling screw. Return the instrument to the starting position and carefully center the bubble. Rotate the instrument 3,200 mils. Any discrepancy noted in the position of the bubble is the appar-

ent error, or twice the actual error, of the horizontal level.

c. To adjust the horizontal level, remove one-half of the apparent error by turning the leveling screws. The remaining error (actual error) is removed by turning the capstan adjusting screw in the right support. The capstan screw is $1\frac{1}{2}$ inches above the horizontal clamping screw. The adjusting pin is used to move the capstan adjusting screw.

104. Optical Plumb Adjustment

a. The purpose of the optical plumb adjustment is to place the center of the rotating axis of the instrument over the ground point.

b. To test the optical plumb, place a plumb bob on the instrument and level carefully. Establish a point on the ground under the plumb bob. Remove the plumb bob. If the image of the ground point is not under the crossline (circle on older models), an adjustment is required.

c. To adjust the optical plumb, move the crossline (circle) over the ground point by turning the optical plumb adjusting screws. Access to the adjusting screws is obtained by removing the screws located $1\frac{1}{4}$ inches to the right and left of the eyepiece of the optical plumb. The adjusting screws are mounted at angles of 120° . Each screw acts against a counterspring located opposite the eyepiece. By very small movements of the screws, the crossline (circle) can be centered over the ground point. The last movement must be clockwise to compress the counterspring. Check the adjustment by rotating the instrument through 6,400 mils. If the crossline (circle) does not remain over the ground point, repeat the adjustment. After the adjustment has been completed, the cover screws should be replaced.

105. Horizontal Collimation Adjustment

a. *Purpose.* The purpose of the horizontal collimation adjustment is to make the line of sight perpendicular to the horizontal axis of the telescope.

b. *Test.* To test the horizontal collimation, take a horizontal reading on a well-defined point with the telescope in the direct position. Plunge the telescope and, with the instrument in the reverse position, take another reading on the same point. These two readings should differ by 3,200 mils. The instrument operator should

repeat both readings to insure that he has not made an error in reading the instrument. Any discrepancy noted between the actual difference in the two readings and 3,200 mils is the apparent error or twice the collimation error. If the discrepancy exceeds plus or minus 1 mil, the crosshairs should be adjusted.

c. *Adjustment.* The horizontal collimation adjustment is made in the following manner. Assume that the reading in the direct position is 150.7 mils and the reading in the reverse position is 3352.9 mils. Using the lateral tangent screw, set the circle to the mean value of the direct and reverse pointings (151.8). Adjust the telescope reticle to the target by turning the adjusting screw. The two adjusting screws are arranged horizontally and opposite each other and are the pull action type. If the reticle must be moved to the right, the left screw should be loosened slightly and the right screw tightened slightly to hold fast. Repeat the test to insure that the proper amount of adjustment has been made.

106. Vertical Collimation Adjustments

a. The purpose of the vertical collimation adjustment is to make the line of sight horizontal when the vertical circle reads 1,600 mils with the telescope in the direct position and 4,800 mils with the telescope in the reverse position.

b. To test the vertical collimation, take a vertical reading on a well-defined point with the telescope in the direct position and with the collimation level bubble centered. Plunge the telescope to the reverse position and take a reverse vertical reading on the same point, with the collimation level bubble centered. The collimation level bubble must be centered before, and checked after, each vertical reading. The sum of the direct and reverse readings should equal 6,400 mils. Any discrepancy between the sum of the two readings and 6,400 mils is the apparent error and is twice the collimation level error. If the discrepancy exceeds plus or minus 1 mil, the collimation level should be adjusted.

c. To adjust the collimation level, place the telescope in the direct position and sight on the point. Compute the correct reading by applying one-half of the index error of the vertical circle to the direct reading. If the sum of the two readings was greater than 6,400 mils, subtract

one-half of the apparent error from the direct reading; if the sum was less than 6,400 mils, add one-half of the apparent error to the direct reading. Place the correct reading on the instrument by using the vertical circle tangent screw. With the correct reading on the instrument, the collimation level bubble will not be centered. The bubble must be brought into coincidence by turning its adjusting screw. Access to the adjusting screw is gained by remov-

ing the cover of the vertical circle level. Repeat the test to insure that the proper amount of adjustment has been made to the collimation level.

107. Verticality of Vertical Crossline Adjustment

The T16 theodolite is built so that the vertical crossline remains vertical. Therefore, the verticality adjustment of vertical crossline is not performed.

CHAPTER 8

THEODOLITE, WILD T2, MIL-GRADUATED

Section I. GENERAL

108. General

a. The Wild T2 theodolite mil-graduated (fig. 28), is used to obtain angular values for artillery fourth-order survey. Both horizontal and vertical angles can be measured with the theodolite. The theodolite is a direction type instrument. The scales, graduated in mils, are readable directly to 0.002 mil and by estimation to the nearest 0.001 mil and may be illuminated by sunlight or artificial light.

b. The T2 theodolite is issued with the following accessories: canvas accessory kit, diagonal eyepieces for the telescope and reading microscope, sun filter, dustcap, jeweler's screwdriver, two adjusting pins, camel's-hair brush, plastic instrument head cover, instruction pamphlet, battery case with lighting devices and three spare bulbs, universal tripod, with plumb bob, plug-in sleeve, and tripod key in leather pouch attached to tripod. Some models of the theodolite have the accessories in the base of the carrying case.

c. The carrying case for the T2 consists of a base plate and a steel, dome-shaped hood. When in the base, the instrument rests on three supports and is fixed to the supports with locking devices. A wooden padded box is also furnished for transporting the theodolite while in its case.

d. The tribrach is that part of the theodolite which contains the three leveling screws and the circular level. The leveling screws are enclosed and dustproof. On models manufactured subsequent to 1956, the tribrach is detachable. A locking device holds the instrument and tribrach together.

e. The theodolite has a plate level and a vertical circle level (split bubble) in addition to

the circular level on the tribrach. The plate level is located between the two standards of the instrument. The vertical circle level is built in, adjacent to the vertical circle. A tangent screw is used to bring the ends of this bubble into coincidence.

f. An optical plumb system is provided on the theodolite for accurate centering over the station. The system is located in the tribrach of the instrument.

g. The horizontal clamp (fast motion) and the horizontal tangent screw (slow motion) for moving the theodolite in azimuth are located on opposite sides of the instrument on the lower portion of the alidade. The clamping screw for the vertical circle (fast motion) and the vertical circle tangent screw (slow motion) for moving the telescope vertically are located one above the other on the standard which holds the vertical circle. These tangent screws and clamps are shown in figure 28.

h. The 28-power telescope of the T2 theodolite can be reversed. The crosslines are focused by turning the eyepiece; the image, by turning the focusing ring. An object when viewed through the telescope is inverted.

i. An exterior tilting mirror located on the lower portion of the alidade illuminates the horizontal circle. Another exterior tilting mirror located on the standard which holds the vertical circle illuminates the vertical circle. The circle selector knob is inscribed with a heavy line. When the line is horizontal, the horizontal circle may be viewed through the circle-reading eyepiece. When the line is vertical, the vertical circle may be viewed. The

circle selector knob is located above the inscription "Wild."

j. An electric illumination device is issued with the T2 theodolite. In the lower housing of the theodolite is a socket to receive a plug from the battery case. The tilting mirrors are replaced with lamps in bulb holders. A rheostat is provided on the battery case for adjusting the amount of light. Crossline illumination is adjusted through the use of the illuminating mirror for telescope diaphragm.

k. Standard equipment includes diagonal eyepieces for both the telescope and the circle-reading microscope. A sun filter is provided for the telescope eyepiece for viewing the sun.

l. The Wild universal tripod issued with the

theodolite has sliding legs. The overall length of the closed tripod is 3 feet; the extended length is 5.2 feet. A leather pouch attached to the tripod contains a plumb bob with a plug-in sleeve and wrench for the tripod legs. The head of the tripod is covered with a screw-on protector cap.

109. Setting up the Tripod

The tripod used with the T2 theodolite is the same as that used with the T16 theodolite. Therefore, the same procedure may be used for setting up the tripod (par. 89).

110. Removing the Theodolite from its Case

The T2 theodolite is removed from its case in

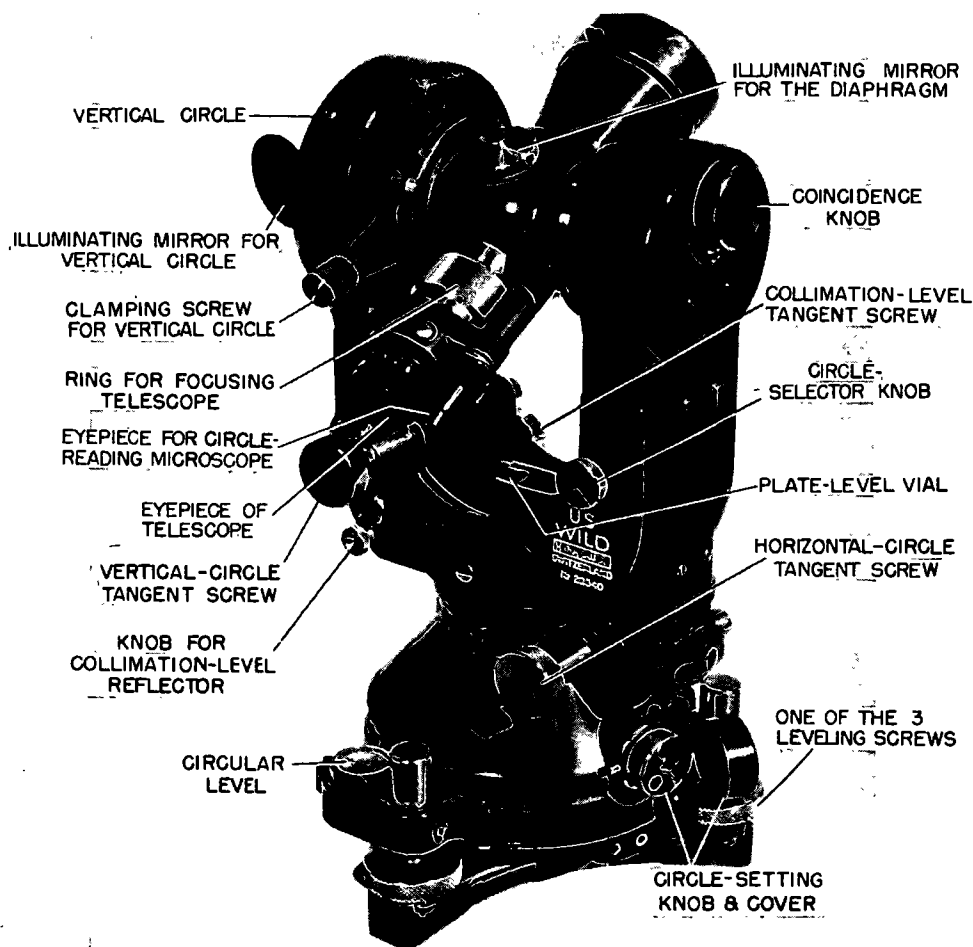


Figure 28. The Wild T2 theodolite.

the same manner as the T16 theodolite (par. 90), except that it is fastened to the base by three supports with locking devices.

111. Plumbing the Theodolite

The T2 theodolite is plumbed over a station in the same manner as the T16 theodolite (par. 91).

112. Leveling the Theodolite

The T2 theodolite is leveled in the same manner as the T16 theodolite (par. 92).

Section II. USE OF THEODOLITE

115. Circle Readings

a. A system of lenses and prisms permits the observer to see small sections of diametrically opposite sides of either the horizontal circle or the vertical circle (fig. 29). The circles are viewed through the circle-reading microscope, the eyepiece of which is alongside the telescope eyepiece. The circle to be viewed is selected by turning the circle selector knob on the right standard. The field of view of the circle-reading microscope appears to contain two small windows (fig. 30). The upper window contains images of two diametrically opposite portions of a circle (horizontal or vertical). One of the images of the circle is inverted and appears above the other image. The lower window contains an image of the portion of the micrometer scale.

b. The coincidence knob on the side of the right standard is used to obtain readings for either of the circles in conjunction with the micrometer scale. Optical coincidence is obtained between diametrically opposite graduations of the circle by turning the coincidence knob. When this knob is turned, the images of the opposite sides of the circle move in opposite directions across the upper window in the circle-reading microscope. The image of the micrometer scale in the lower window also moves. The graduations on the circle (main scale) are brought into coincidence so that they appear to form continuous lines. The center of the field of view is marked by a vertical line. This vertical line is not used in reading the circle.

c. The main scale (upper window) is graduated in two-mil increments. Each fifth gradua-

113. Adjustment to Eliminate Parallax

The telescope of the T2 theodolite is similar to the telescope of the T16 theodolite, and the adjustment to eliminate parallax is accomplished in the same manner (par. 94).

114. Taking Down the Theodolite

The T2 theodolite is taken down and placed in its carrying case in the same manner as the T16 theodolite (par. 95). All fast motions are clamped and the dustcap is returned to the objective end of the telescope.

tion is numbered. The unit digit is omitted, i.e., 10 mils appear as 1; 250 mils as 25; 3510 mils as 351.

d. The micrometer scale (lower window) is graduated from 0.000 mil to 1.000 mil. Each 0.002 mil is marked with a graduation, and each fifth graduation is numbered (hundredth of a mil). The scale may be read to 0.001 mil by interpolation.

116. Horizontal Circle Readings

To determine a reading on the horizontal circle—

a. Rotate the circle selector knob until the black line on the face of the knob is horizontal.

b. Adjust the illuminating mirror so that both windows in the circle-reading microscope are uniformly lighted.

c. Focus the microscope eyepiece.

d. Observe the images in the microscope. Bring the circle graduations into coincidence at the center of the upper window, using the coincidence knob.

e. Read the circles.

117. Steps in Circle Reading

The steps in reading the circles are (fig. 30):

a. Determine the first erect numbered graduation to the left of the vertical line that marks the center of the upper window. The number which labels this line indicates the number of tens of mils. In figure 30, this number is 207.

b. Locate the inverted graduations which differs from 207 by 320, this number is 527 (viewed 129). The inverted number will always be to the right of the vertical line which marks

the center of the field of view. Both values will always end in the same number, in this case number 7.

c. Starting from 207, count the number of graduations to the inverted 527. There are six graduations, representing 6 mils. Each graduation represents 1 mil.

d. Convert 207, which is tens of mils, to 2,070 mils ($2,070 + 6 = 2,076$ mils, the angular value obtained from the main scale).

e. The vertical line which marks the center of the field of view indicates the value to be read

on the micrometer scale (lower window). In figure 30, this value is 0.254 mil.

f. Add the angular values determined in d and e above; $2,076 + 0.254 = 2,076.254$ mils, the angular value.

118. Vertical Circle Readings

The circle selector knob is rotated until the black line on the face of the knob is vertical. The vertical circle may now be viewed in the microscope eyepiece. A reading on the vertical circle is determined in the same manner as a reading on the horizontal circle.

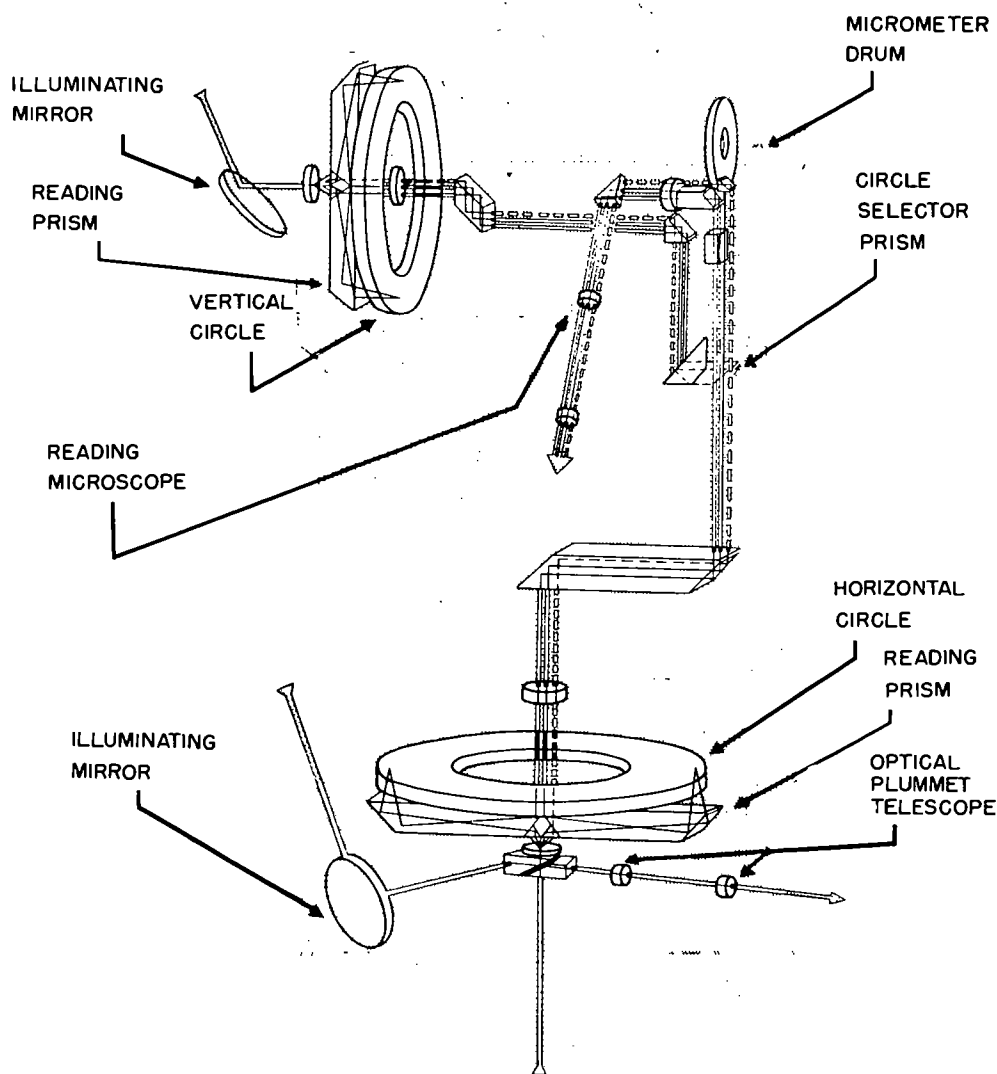


Figure 29. Circle-reading optical system of the Wild T2, theodolite.

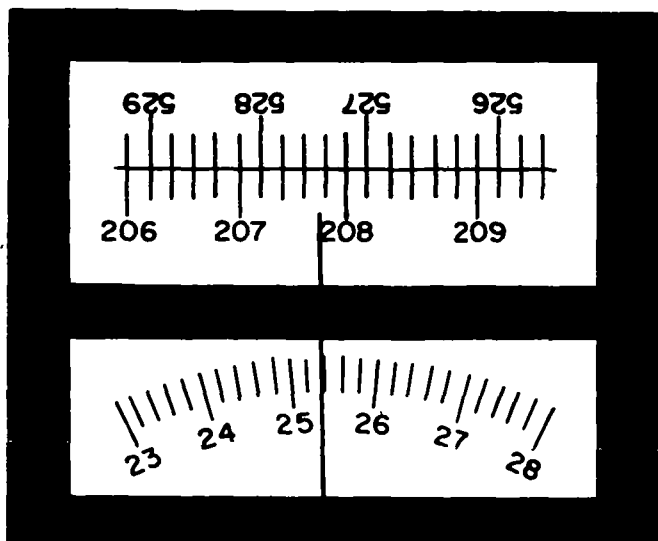


Figure 30. Scale images viewed through the circle-reading microscope, mil-graduated T2 theodolite.

119. Setting the Horizontal Circle

There are two cases when it is necessary to set the horizontal circle.

a. In the first case, the circle is set to read a given value with the telescope pointed at a target. The initial circle setting 0.150 (± 0.100 mils) is used as an example.

- (1) Point the instrument at the target.
- (2) With the coincidence knob, place 0.150 mil on the micrometer scale.
- (3) With the circle setting knob, attempt to zero the main scale, insuring that the numbered lines which are 3,200 mils apart are touching each other.
- (4) With the coincidence knob, bring the main scale graduations into a more perfect coincidence.
- (5) Read the horizontal circle. It should read 0.150 (± 0.100 mil). With extreme care, which is time-consuming, a circle may be set to an accuracy of 0.010 mil.

b. In the second case, it is desired to lay the instrument on a line of known direction from a reference direction.

- (1) Point the instrument on the line for which the reference direction is provided and read the circle.
- (2) Add the angular difference between the reference direction and the desired

direction to the circle reading. The resultant reading represents the reading for the instrument when it is pointed in the desired direction.

- (3) Set on the micrometer scale, to the thousandth of a mil, the reading to be set on the circle to place the instrument on the desired direction.
- (4) Turn the instrument with the azimuth clamp and tangent screw and obtain coincidence on the main scale at the mil values corresponding to the reading obtained in step (2) above. When coincidence is obtained, the instrument is pointing in the desired direction.

120. Measuring Horizontal Angles

a. The T2 theodolite is a direction instrument. The procedures in measuring horizontal angles are (figs. 31 and 32):

- (1) With the telescope in the direct position, point to station A and record the initial circle setting (0.166 mil).
- (2) With the telescope in the direct position, point to station B and record the circle reading (1215.475 mils).
- (3) Reverse the telescope and point to station B and record the circle reading (4415.503 mils).
- (4) With the telescope in reverse position, point to station A and record the circle reading (3200.200 mils).
- (5) Subtract 3,200 mils from the reverse pointing on station A and mean the

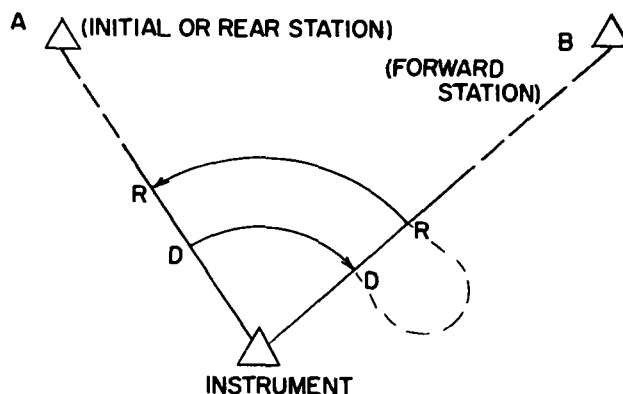


Figure 31. Determining the horizontal angle between stations A and B.

STATION	T	HORIZONTAL X MILS	MEAN	VERTICAL READING	VERTICAL X MILS
A	D	0000.166			
	R	3200.200	0000.183		
INST					
	MN	1215.306			+28.624
B	D	1215.475		1571.384	+28.616
	R	4415.503	1215.489	4828.631	+28.631

Figure 32. Field notes for recording measurements of angle, one position with the mil-graduated T2 theodolite.

remainder with the direct point on station A (0.183 mil).

- (6) Subtract 3,200 mils from the reverse pointing on station B and mean the remainder with the direct pointing on station B (1215.489 mils).
- (7) Subtract the mean pointing on station A ((5) above) from the mean pointing on station B ((6) above) ($1215.489 - 0.183 = 1215.306$ mils). The difference is the horizontal angle between stations A and B (1215.306 mils).

Note. Procedures (1) through (7) consist of one direct and one reverse pointing on each station and are referred to as one position.

b. When it is necessary to measure the angle to more than one station, a pointing is made on the initial station with the telescope in the direct position and then on each station around the horizon in a clockwise direction. After a reading is obtained on the last clockwise station with the telescope direct, the telescope is reversed and a pointing is made on each station in a counterclockwise direction, ending with the initial station. One set of direct and reverse pointings on all of the observed stations constitutes one position.

c. For each position there is a direct and a reverse pointing on each observed station. The direct pointing and the reverse pointing on each station should differ by 3,200 mils plus or minus

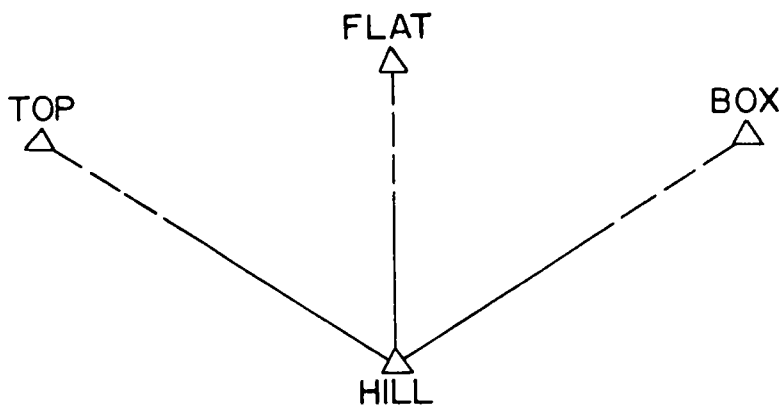
the amount of horizontal spread (twice the error in horizontal collimation) in the instrument. No value can be specified as the maximum allowable spread for an instrument; however, it should be small (0.150 mil or less) for convenience in meaning the pointings. The amount of spread should be constant; otherwise, there are errors in the pointing.

d. In artillery survey, one position is taken in traverse and two positions are taken in triangulation. If the primary requirement of the traverse is an accurate direction (FA missile battalion), then two positions are taken.

e. The initial circle settings should be as follows: first position, 0.150 (± 0.100) mils; second position, 4800.150 (± 0.100) mils.

f. When it is necessary, as in triangulation, to measure two positions, the second position is measured in the same manner as the first position, except that the second position is started with the telescope in the reverse position, pointing on the initial station.

g. To determine the angle between two observed stations, the mean horizontal circle reading to each station is determined; and then the difference between the mean circle readings is determined. When two positions are taken, the value of the angle determined from the first position is meaned with the value of the angle determined from the second position. Figure 33 is an example of the method of recording



STATION	T	HORIZONTAL * MILS	MEAN	VERTICAL READING	VERTICAL * MILS
TOP	D	0000.112			
	R	3200.134	0000.123		
HILL *		(819.236)			(-10.320)
FLAT	D	0814.338		1610.314	-10.314
	R	4014.380	0814.359	4789.673	-10.327
HILL *		(896.669)			(+31.051)
BOX	D	1711.010		1568.940	+31.060
	R	4911.046	1711.028	4831.042	+31.042
				MEAN HORIZ. *	
TOP	R	4800.176		(819.236)	ANGLE FROM FIRST POSITION
	D	1600.166	4800.171	(819.202)	ANGLE FROM SECOND POSITION
HILL *		(819.202)		(819.219)	MEAN ANGLE AT HILL FROM TOP TO FLAT
FLAT	R	5614.389		896.669	
	D	2414.357	5614.373	896.627	
HILL *		(896.627)		(896.648)	MEAN ANGLE AT HILL FROM FLAT TO BOX
BOX	R	0111.016			
	D	3310.984	0111.000		

Figure 33. Field notes for recording measurements of two angles, two positions with the mil-graduated T2 theodolite.

horizontal circle readings and determining horizontal angles between three stations, with two positions observed.

h. When two positions are used, if the two observed values for any angle differ by more than 0.050 mil, these observed values should be rejected.

i. If the observed value(s) are rejected, the angle(s) will be reobserved using approximately the same initial circle setting which was used to obtain the rejected value(s).

121. Measuring Vertical Angles

a. Vertical angles cannot be measured directly with the theodolite. Instead, the vertical angle to an observed station is computed from a vertical circle reading to the station. When the collimation level bubble is centered, vertical circle readings are measured from a line which is, in effect, an upward extension of the plumb line of the theodolite (fig. 34). One determination of the vertical angle is computed from the vertical circle reading with the telescope of the instrument pointed at the station in the direct position. With the telescope direct, the vertical angle is equal to 1,600 mils minus (—) the vertical circle reading. A second determination of the vertical angle is computed from the vertical-circle reading with the telescope pointed at the station in the reverse position. With the telescope reversed, the verti-

cal angle is equal to the vertical circle reading minus (—) 4,800 mils. The two determinations of the vertical angle then are meant to obtain the vertical angle to the observed station (fig. 33).

b. For reading the vertical circle in conjunction with readings of the horizontal circle, the first (direct) vertical circle reading is taken immediately after taking the direct horizontal circle reading. The second (reverse) vertical circle reading is taken before taking the reverse horizontal circle reading. After the cross-lines have been placed on the station, the telescope is elevated (or depressed) until the horizontal crossline is exactly on the point to which the vertical angle is desired. The vertical angle generally is read to the height of instrument (HI).

c. For reading the vertical circle, after sighting on the observed station, *the bubble of the collimation level (split bubble) is brought to the center of its vial.* This is accomplished by rotating the collimation level tangent screw until the images of the ends of the bubble coincide. The vertical circle reading then is read in the circle-reading microscope. The vertical scales are read in the same manner that the horizontal scales are read. Figure 33 is an example of the method of recording vertical circle readings and determining the vertical angles.

Section III. CARE AND MAINTENANCE

122. Care of Theodolite

The T2 theodolite is a delicate instrument. Care must be taken not to drop or bump it against any object. If the instrument gets wet, remove all outside moisture and as soon as possible place the instrument in a warm, dry room or tent. When the instrument is moved from station to station, a man on foot may carry the instrument, mounted on its tripod, under one arm, with the hand of the other arm under the tribrach of the instrument. All motions should be clamped with the telescope pointed upward. When the theodolite is carried over rough terrain, the instrument should be transported in its carrying case. When transported in a vehicle, the theodolite should be carried in the dome-shaped carrying case, and the case

should be in the padded box. For short distances, the carrying case may be carried in an upright position on the instrument operator's lap.

123. Cleaning the Theodolite

The theodolite must be kept clean and dry. During use, as necessary, and after use, the instrument should be cleaned as follows:

a. Painted surfaces should be wiped with a clean cloth.

b. The exterior of the eyepieces and the objective lens of the telescope first should be brushed with a camel's-hair brush to remove dust and then wiped with lens tissue to remove moisture. *Care must be taken not to scratch the lenses or the coating on the lenses.*

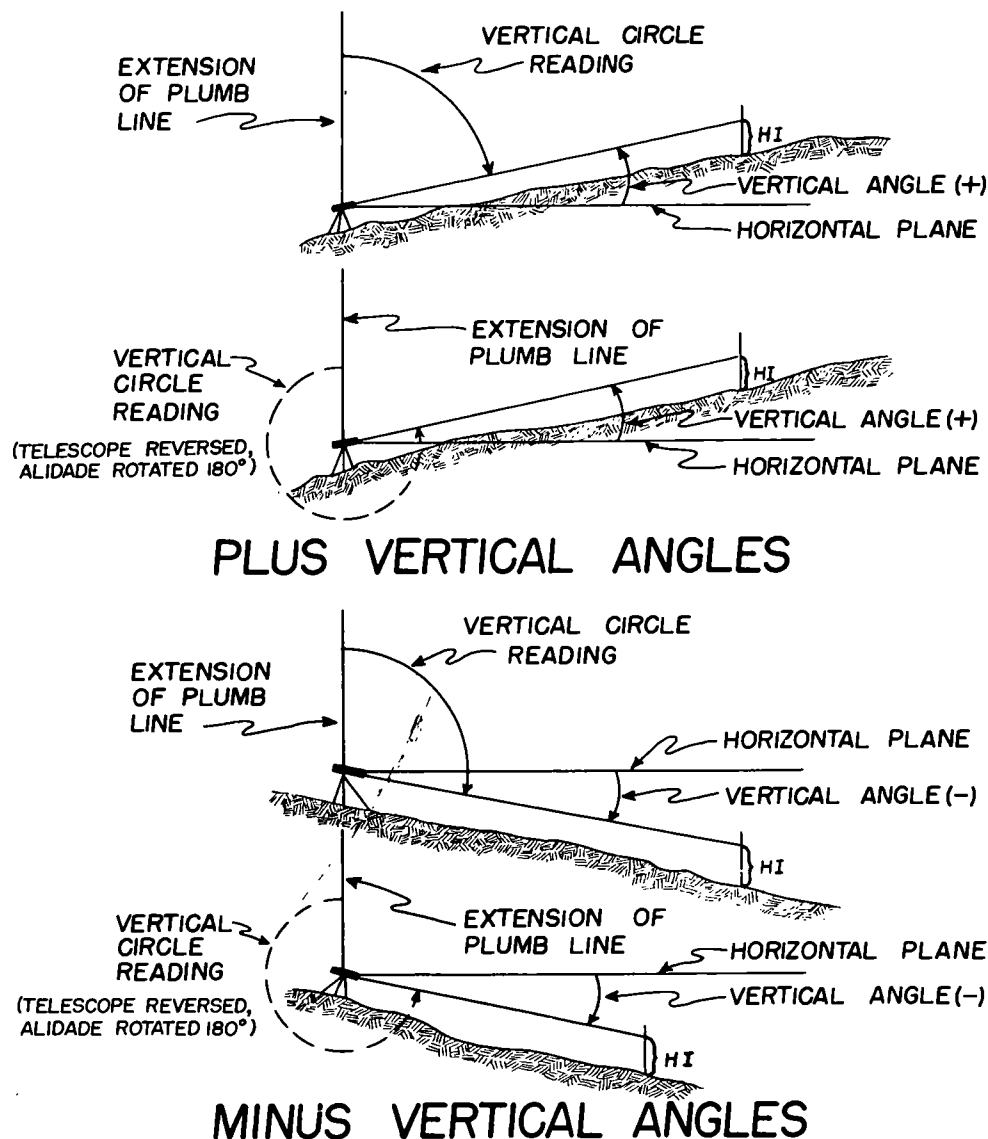


Figure 34. Relation of vertical circle readings and vertical angles.

c. The tripod should be kept clean, and moving parts should be oiled lightly.

124. Repair of Theodolite

Adjustment (except as explained in pars. 125-131) and repair of the theodolite must be performed by *qualified instrument repair personnel*. Artillery units should turn theodolites in for necessary adjustment and repair to the engineer unit which is responsible for providing maintenance service.

125. Adjustment of Theodolite

a. The theodolite must be kept in correct adjustment if accurate results are to be obtained. There are five tests and adjustments of the theodolite that should be made periodically, in the sequence in which they are discussed in paragraphs 126 through 130. When any test indicates that an adjustment is necessary, this adjustment should be made and tested for correctness before proceeding with the next test.

b. The five tests and adjustments of the theodolite are made while the instrument is mounted on its tripod and leveled accurately. For these tests and adjustments, the instrument should be set up in the shade, on firm ground, with the head of the tripod as nearly level as possible. The theodolite should also be protected from the wind.

126. Plate Level Adjustment

a. *Purpose.* The purpose of the plate level adjustment is to make the vertical axis of the theodolite truly vertical when the bubble of the plate level is centered in its vial.

b. *Test.*

- (1) Turn the instrument until the plate level is parallel to the line through two leveling screws. With these two leveling screws, center the bubble of the plate level.
- (2) Turn the instrument through 1,600 mils and center the plate level bubble by turning the third leveling screw.
- (3) Repeat (1) and (2) above, until the bubble will come to rest centered in its vial in both of these positions.
- (4) Turn the instrument through 3,200 mils from its position in (1) above. If the plate level is correctly adjusted, the bubble will come to rest at the center of its vial with the instrument in this position.

c. *Adjustment.*

- (1) If the plate level bubble comes to rest off center in b(4) above, move the bubble halfway back toward center by turning the leveling screws.
- (2) With the capstan head adjusting screw below the collimation level illuminator, bring the bubble of the plate level to the center of its vial.
- (3) Repeat the test (b above) and make any additional adjustment of the plate level that is required.

d. *Frequency of Test and Adjustment.* The adjustment of the plate level should be tested every time the theodolite is set up for use.

127. Optical Plummet Adjustment

a. *Purpose.* The purpose of the optical plummet adjustment is to make the vertical axis of

the theodolite pass through the station marker when the theodolite is properly leveled and when the station marker is centered in the reticle circle (crossline) of the optical plummet.

b. *Test.*

- (1) Suspend the plumb bob from the leveled instrument and mark a point on the ground exactly under the point of the plumb bob. Remove the plumb bob from the instrument.
- (2) Check the leveling of the instrument, and then look into the eyepiece of the optical plummet. If this plummet is correctly adjusted, the mark on the ground ((1) above) will be centered in the reticle circle of the plummet.

c. *Adjustment.* If the station point is not centered in the optical plumbing assembly reticle, bring it to center by means of three adjusting screws located near the optical plummet eyepiece. With an adjusting pin, loosen the retaining nut and raise or lower the reticle by moving the adjusting screw. Adjust either of the side adjusting screws. Moving the screw, with the retaining nut loosened, raises or lowers the reticle crosslines or circle in the same direction the screw travels. The two side adjusting screws move the crosslines or circle in the opposite direction from their travel. When the crossline or circle is centered over the station point, lock the lower adjusting screw by tightening the retaining nut.

128. Verticality of Vertical Crosshair Adjustment

a. *Purpose.* The purpose of the verticality adjustment is to make the vertical crosshair lie in a plane that is perpendicular to the horizontal axis of the instrument.

b. *Test.*

- (1) Select a well-defined distant point as near the same horizontal plane as the instrument as possible.
- (2) Center the vertical crossline of the telescope on the selected point. With the vertical tangent screw, elevate and depress the telescope. If the vertical crossline continuously bisects the point, the adjustment is correct.

c. Adjustment. If the vertical crossline does not continuously bisect the sighted point, rotate the telescope reticle to a point where the crossline will bisect the point throughout the elevation and depression of the telescope. The crossline ring may be rotated by turning the slant screws located between the focusing ring and eyepiece in opposite directions.

129. Horizontal Collimation Adjustment

a. Purpose. The purpose of the horizontal collimation adjustment is to make the line of sight perpendicular to the horizontal axis of the telescope.

b. Test.

- (1) Select a well-defined distant point.
- (2) Center the vertical crossline on the selected point.
- (3) Read the horizontal circle with the telescope in the direct position and then with the telescope in the reverse position. Determine the difference (spread) between the direct pointing and reverse pointing. This is done as follows:

0000.200 mil (direct reading)
3200.800 mils (reverse reading)
3200.600
3200.000
0000.600 mil (spread between direct and reverse pointings)

Note. The instrument should be adjusted if the spread is more than 0.150 mil.

c. Adjustment.

- (1) The horizontal circle reading (direct position) was 0.200 mil while pointed on the selected point. The spread is 0.600 mil. Add one-half the spread to the direct reading ($0.200 + 0.300 = 0.500$).
- (2) With the coincidence knob, set 0.500 mil on the micrometer scale. This is the mean direct and reverse pointing.
- (3) Bring the main scale graduation lines into coincidence, using the horizontal circle tangent screw (slow motion).
- (4) Place the vertical crossline on the selected point by sliding the crossline diaphragm. To slide the diaphragm, loosen (tighten) the two screws in

slant position on the right side of the telescope the same amount, while at the same time tighten (loosen) the single screw on the left.

- (5) Repeat the test and adjustment procedure until the spread between direct and reverse pointings is less than 0.050 mil.

130. Vertical Collimation Adjustment

a. Purpose. The purpose of the vertical collimation adjustment is to make the line of sight horizontal when the vertical circle reading is 1,600 mils in the direct position or 4,800 mils in the reverse position.

b. Test. Select a well-defined distant point. Make a direct and a reverse circle reading. Determine the sum of the vertical circle readings. The sum will be 6,400 mils plus or minus ($\pm$) the vertical circle spread. This is done as follows:

1243.400 mils (direct reading)
5156.100 mils (reverse reading)
6399.500
6400.000
0000.500 mil (vertical circle spread)

Note. The instrument should be adjusted if the spread is more than 0.150 mil.

c. Adjustment.

- (1) The vertical circle reading (direct position) is 1243.40 mils. The spread is 0.500 mil and must be applied to the direct reading with the appropriate sign. Subtract one-half the spread from the direct reading ($1243.400 - 0.250 = 1243.150$).
- (2) Place the telescope in direct position on the distant point. With the coincidence knob, set 0.150 on the micrometer scale.
- (3) With the collimation level (split bubble) tangent screw, bring the main scale graduation lines into coincidence. The telescope is now pointed at the distant point with the mean direct and reverse reading on the vertical circle (1243.250).
- (4) Aline the images of the ends of the collimation level bubble (split bubble),

using the two level adjusting screws. These screws are located immediately under the collimation level. Both screws should be rotated the same amount in opposite directions.

- (5) Repeat the test and adjustment proce-

dures until the vertical circle spread is less than 0.050 mil.

131. Maintenance

For maintenance responsibilities, see TM 5-6675-213-12, Operator's and Organizational Maintenance Manual.

Section IV. SEXAGESIMAL THEODOLITE WILD T2

132. General

a. The T2 theodolite, mil-graduated, is the authorized instrument for obtaining angular values for artillery fourth-order survey. However, until the mil-graduated T2 theodolite is available, the sexagesimal T2 theodolite will be used in artillery fourth-order survey.

b. The mil-graduated theodolite and the sexagesimal theodolite are identical except for the graduations of the horizontal and vertical circles. This section will deal with the differences in the circles. Both instruments are operated in the same manner.

133. Reading Circles

The circle is viewed through the circle-reading microscope (fig. 35). The upper window is the main scale, the graduations are spaced at 20-minute intervals, and every third graduation

is numbered to indicate a degree. The lower window is the micrometer scale and is graduated in minutes and seconds from 0 second to 10 minutes. The scale may be read to 1 second.

134. Steps in Reading Circles

The steps in reading the circles are as follows (fig. 35):

a. Determine the first erect numbered graduation to the left of the vertical line that marks the center of the upper window. The number which labels this line indicates the number of degrees. In figure 35 this number is 285°.

b. Locate the inverted graduation which differs from 285° by 180°, this number is 105° (viewed 901). The inverted number will always be to the right of the vertical line which marks the center of the field of view. Both values will always end in the same number, in this case number 5.

c. Starting from 285, count the number of spaces between the graduations determined in a and b above. Each space represents 10 minutes in the reading. In figure 35, there are five spaces, representing 50 minutes.

d. The angular value obtained from the main scale (upper window) is 285°50' ($285^\circ + 50' = 285^\circ 50'$).

e. The vertical line which marks the center of the field of view indicates the value to be read on the micrometer scale (lower window). In figure 35, this value is 1'54".

f. Add the angular values determined in d and e above ($285^\circ 50' + 1'54'' = 285^\circ 51'54''$, the angular value).

Note. The horizontal and vertical circles are read in the same manner.

135. Setting the Horizontal Circle

The procedures for setting the horizontal circle of the sexagesimal theodolite are identical to those for the mil-graduated T2 theodolite. However, the initial circle setting when measur-

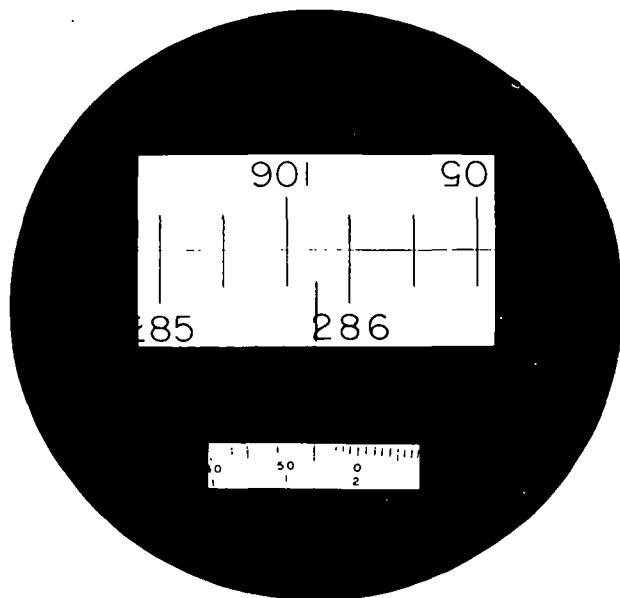


Figure 35. Scale images viewed in circle-reading microscope of sexagesimal T2 theodolite.

ing angles should be $0^{\circ}00'30'' \pm 20''$. When measuring two positions, the initial circle setting for the second position is $270^{\circ}00'30'' \pm 20''$.

136. Measuring Horizontal and Vertical Angles

The procedures for measuring horizontal and vertical angles are identical to those for the mil-graduated T2 theodolite. When measuring two positions, the mean angle of the first posi-

tion should not differ from the mean angle of the second position by more than $10''$; if it does, the angle must be remeasured. (See fig. 36 for sample of recording and measuring angles with the sexagesimal T2 theodolite.)

137. Adjusting the Theodolite

The adjustments on the sexagesimal T2 theodolite are performed in the same manner as the adjustments on the mil-graduated T2 theodolite (pars. 102–107).

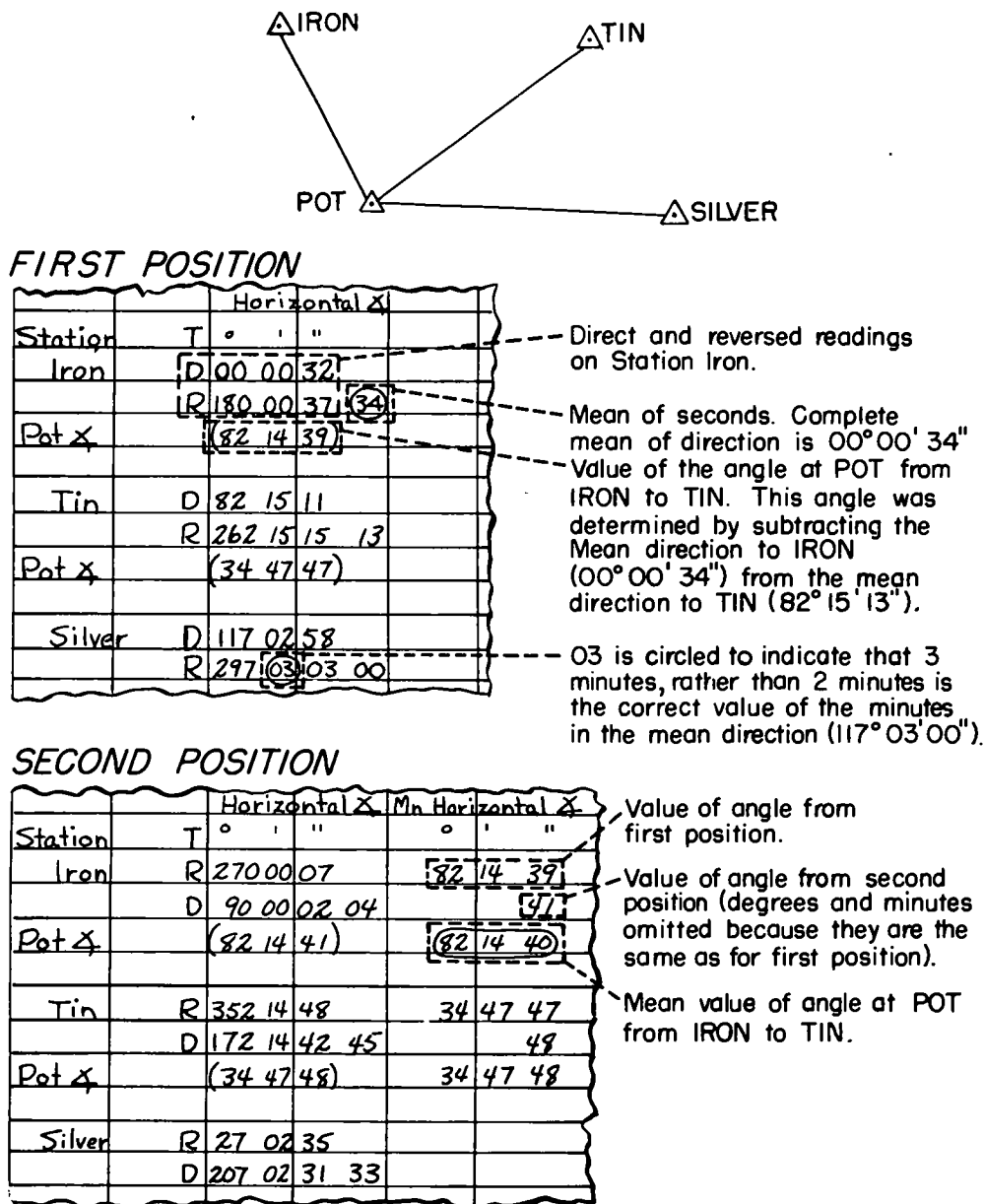


Figure 36. Field notes for recording measurements of two angles, two positions with the sexagesimal T2 theodolite.

CHAPTER 9

TELLUROMETER MRA 1/CW/MV

Section I. GENERAL

138. General

The tellurometer is an electronic distance-measuring device which appears as an item of issue in tables of organization and equipment of artillery units required to perform fourth-order survey (fig. 37). The tellurometer system consists basically of one master and two remote units. The major components for both the master and remote units are described in paragraph 139. Additional items used to complete a tellurometer measurement include the altimeter, tellurometer field record and computations form, and logarithmic tables. Distance is determined by measuring the loop transit time of radio microwaves from the master unit to the remote unit and converting one-half of this loop transit time to distance. Although optical line-of-sight is not required, electrical line-of-sight between the instruments is required. The minimum range capability of the equipment is 152 meters and the maximum range capability is 64,000 meters (40 miles) under ideal conditions. Approximately forty-five minutes is required to measure and compute a distance regardless of the length of the measurement. A distance can be measured during daylight or darkness and through fog, dust, or rain.

139. Description of Components

a. The master and remote units are similar in appearance (figs. 38, 39, and 40) but neither master nor remote unit can be operated in a dual role due to its internal characteristics. The units have the same external dimensions (19 x 19 x 17 inches) and weigh 27 pounds. Both have parabolic reflectors which are shown in the operating position in figure 40. The reflec-

tors have a mirror surface which radiates the received signal to the dipole. The dipoles contain the transmitting and receiving antennas. Both units have identical built-in aerial and



Figure 37. Tellurometer station with operating equipment and carrying case.

communication systems. The luggage-type handle (fig. 40) permits the instrument to be carried when it is not in its case. The hinged door in the lower left hand corner of the control panel (figs. 38 and 39) opens into a compartment in which the radiotelephone handset is stored. A cathode ray tube (CRT) visor (fig. 37) is mounted over the CRT scope to shut out light and make scope presentations more clearly visible.

b. The carrying case (fig. 37) is a light-weight metal alloy, top-opening container. The

lid is provided with a sponge rubber seal for protection against moisture. A luggage-type handle is provided on the top of the lid for transporting short distances. Provision is made on the back of the case for securing the carrying straps for backpacking. Compartments are provided in the container for spare parts, tube visor, and rain cover. The carrying case measures 23 by 12 by 19 inches and weighs approximately 18 pounds.

c. The tripod issued with the tellurometer is the Wild universal tripod, and it is inter-

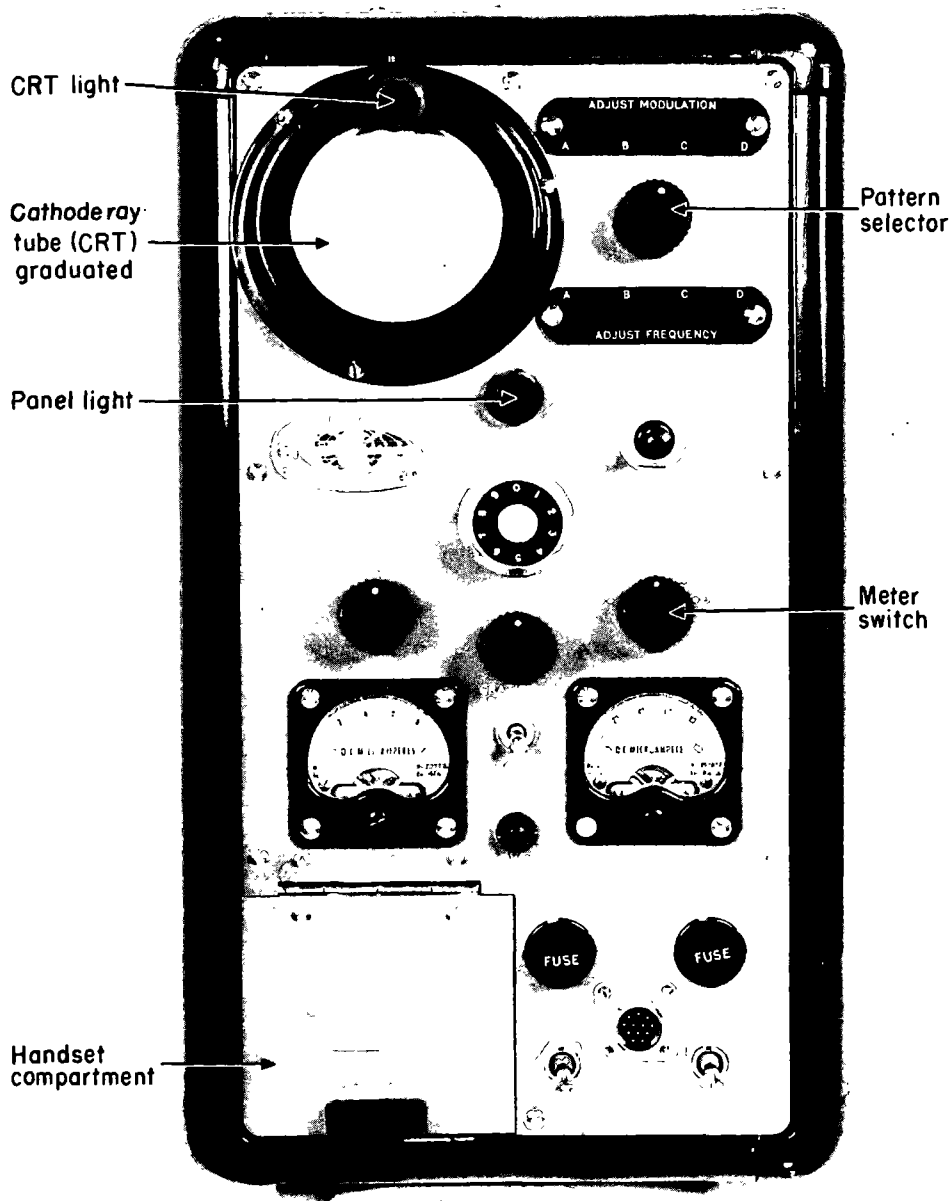


Figure 38. Control panel, master unit.

changeable with the tripod used with the T16 and T2 theodolites.

d. Three different power sources may be used with the tellurometer. A 12-volt, 40-ampere hour battery or a 24-volt, 20-ampere hour battery may be cabled directly to a built-in power pack (figs. 38 and 39). In addition, a 115-volt, 60-cycle or 230-volt, 50-cycle power supply can be utilized through the use of a *mains converter* (external power pack). A fully charged battery will permit 4 to 6 hours of continuous opera-

tion. An 18-foot cable is provided to permit the built-in power pack to be connected to the battery in a vehicle for 24-volt operation.

e. The spare parts kit consists of a small metal box containing tubes, regulators, lamps, and fuzes. A list of these spare parts is provided in the metal container.

f. Additional accessories include a harness (back straps) and pack, tube visor, plastic rain cover, metal screwdriver, nonmetallic screw-

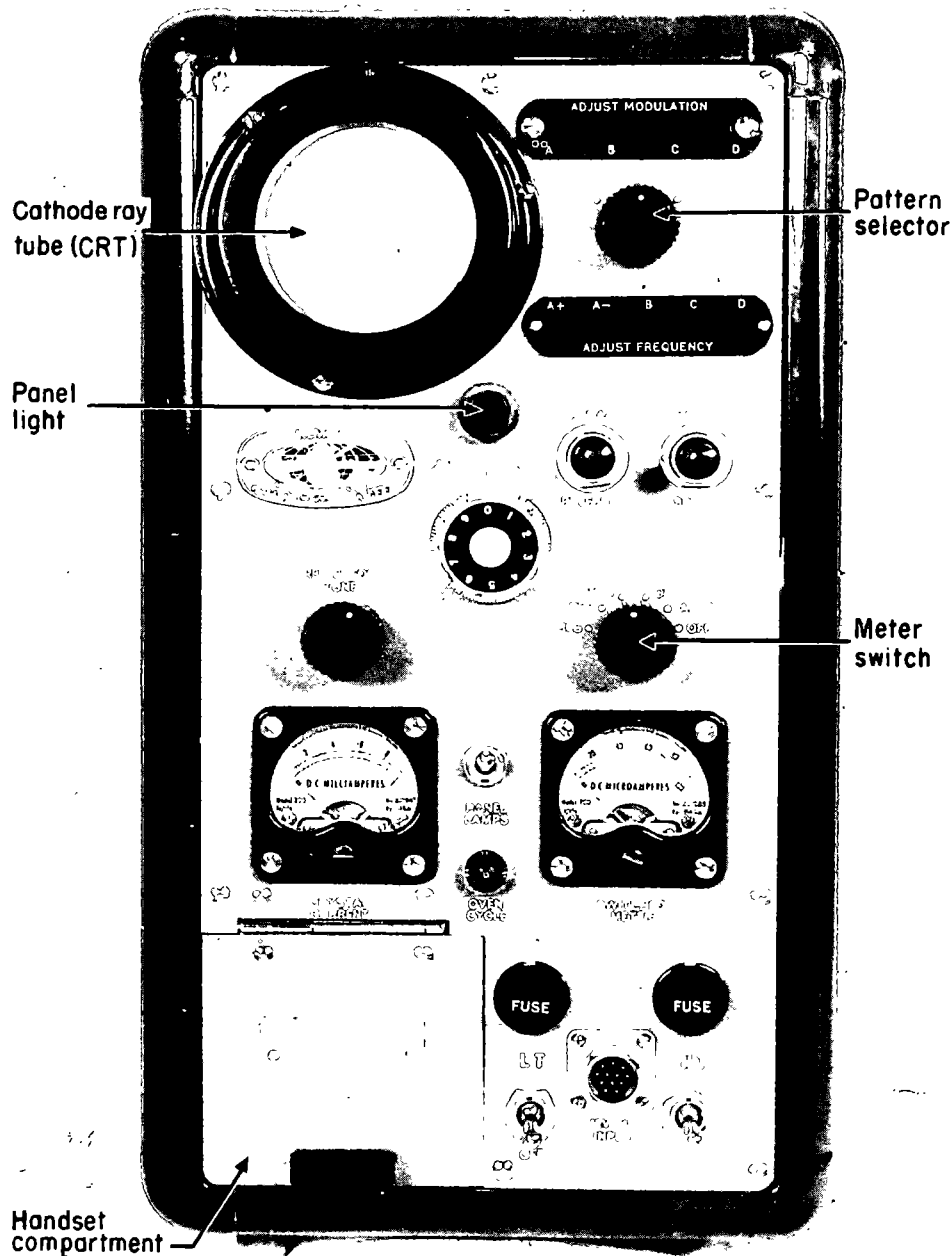


Figure 39. Control panel, remote unit.

driver, two power supply cables, mains converter, Handbook—Operation and Maintenance, and Preliminary Maintenance Support Manual.

g. A surveying altimeter, issued as a separate TOE line item, should be available with each master or remote unit for the determination

of difference in height when it is not possible to measure the vertical angle between master and remote units with an optical instrument. The vertical angle or difference in height is necessary to convert the slope distance measured with the tellurometer to horizontal distance.

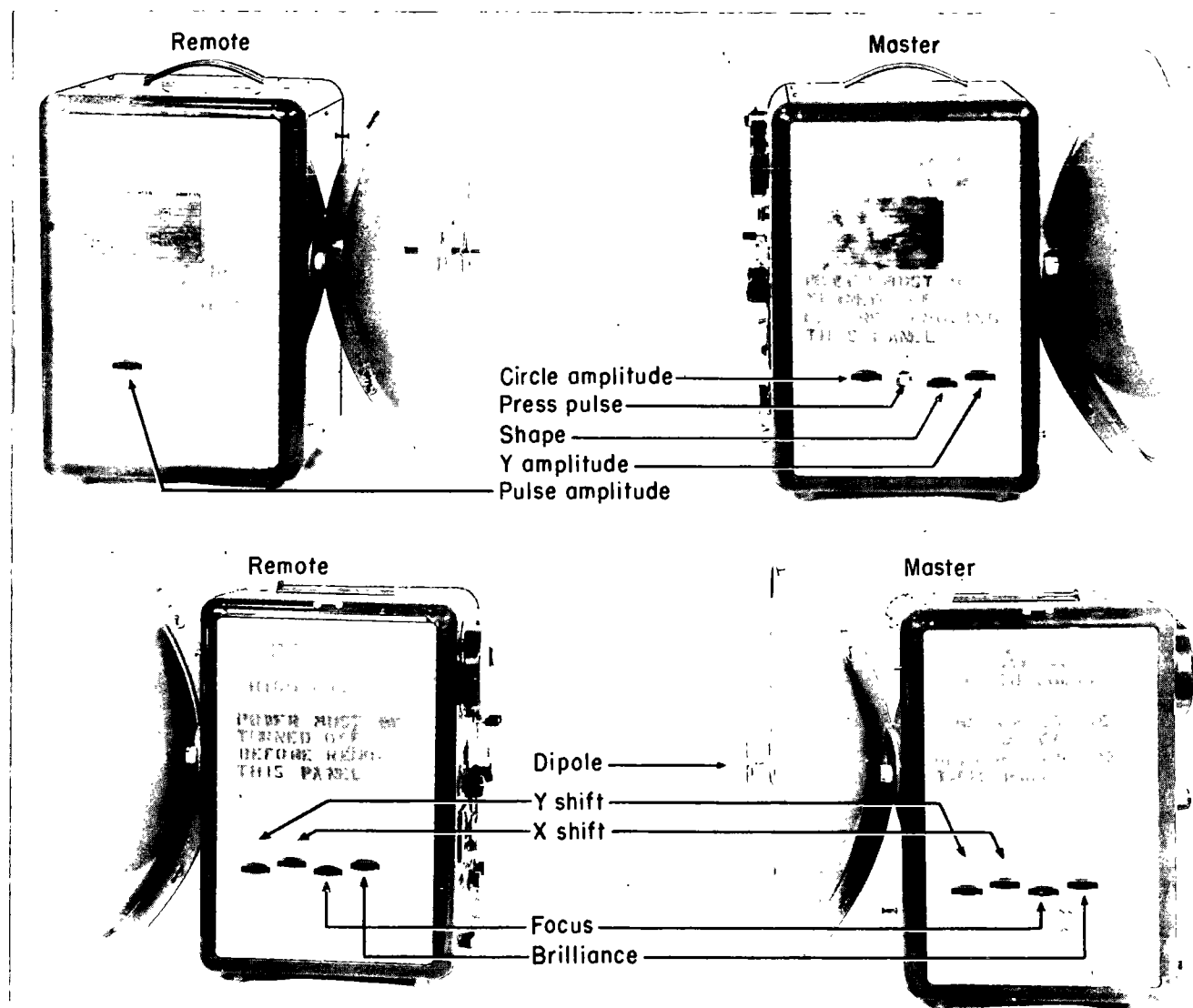


Figure 40. Side views of master and remote units.

Section II. PRINCIPLES OF OPERATION

140. General

a. To perform a distance measurement with the tellurometer system, one master unit and one remote unit must occupy opposite ends of the line to be measured. A continuous radio

wave of 10-centimeter (cm.) wavelength (3000 megacycles) is radiated from the master unit. This radio wave is modulated by what may be referred to as pattern frequency. The modulated wave is received at the remote unit and, in effect, reradiated from the transmitted system

of the remote unit back to the aerial system of the master unit.

b. At the master unit, the return wave is compared with the transmitted wave, and the phase comparison or difference in the two waves is indicated on the circular sweep of the master unit cathode ray tube (CRT) in the form of a small break which marks the phase on a circular scale (fig. 41). The CRT graticule is divided into 10 major and 100 minor graduations. The leading edge of the break in the circular sweep is read clockwise to the smallest minor graduation.

c. In effect, the transit time required by the wave to travel from the master unit to the remote unit and back is determined. The transit time is determined from a series of readings on the master cathode ray tube.

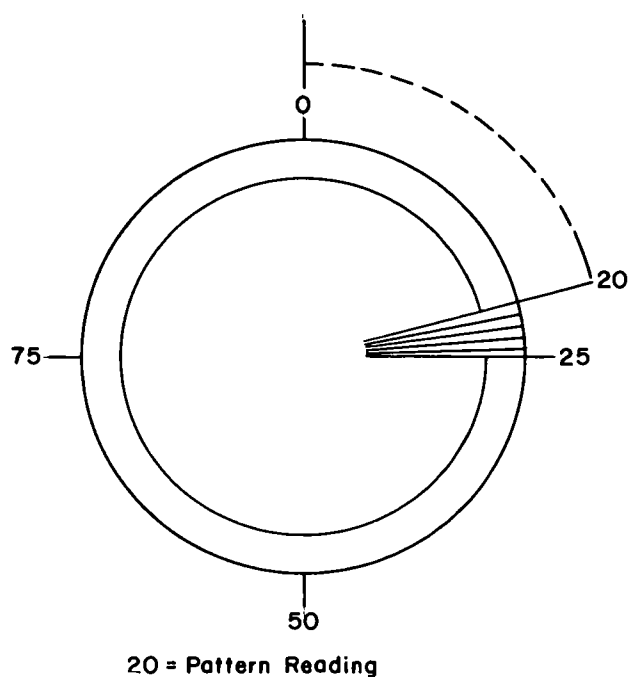


Figure 41. Cathode ray tube pattern reading.

141. Carrier Wave Modulating Frequencies

a. The continuous carrier wave of approximately 2,800 to 3,200 megacycles is emitted at the antenna. This wave is modulated by a series of pattern frequencies as follows:

Pattern	Frequency master (mcs)	Remote (mcs)
A	10,000	9.999
B	9.990	9.989
C	9.900	9.899
D	9.000	8.999
A-	None	10.001

b. All of the frequencies are provided from quartz crystals, the A crystal being accurately set by reference to some standard, such as the 10 megacycles per second (mcs) signal radiated by the Bureau of Standards in Washington. The B, C, and D crystal may drift from specific frequencies to some degree, but, since they indicate only coarse increments of a measurement as will be shown later, this drift is not critical.

142. Phase Comparison

a. Phase comparison is the determination of the difference between the phase of one wave and the phase of another at the same instant. With the tellurometer, it is the difference between the phase of the transmitted wave and the phase of the wave returned to the master unit.

b. With a pattern frequency of 10 mcs, a complete rotation of the phase indication on the graduated scale represents a change of 100 millimicroseconds in the transit time of the wave from master unit to remote unit and back. The graticule of the CRT has 100 divisions representing 100 millimicroseconds. Each minor division represents 1 millimicrosecond and, since radio waves travel at the speed of light (186,310 miles per second), is equivalent to approximately 6 inches. A complete rotation of phase is equal to approximately 15 meters. The 10 mcs pattern or A pattern phase indicates the final two figures of the transit time in millimicroseconds or the final 15 meters of the entire measurement. Since the number of rotations of the A pattern phase cannot be determined, the B, C, and D patterns are introduced to increase the wavelength. The differences between the A pattern reading and the B, C, and D pattern readings, respectively, give phase readings relative to the difference frequency of the modulations, and coarse patterns are derived to determine relative portions of the distance as follows:

A minus D—1000 kcs pattern—150 meters
 A minus C—100 kcs pattern—1,500 meters
 A minus B—10 kcs pattern—15,000 meters

c. Based on the A minus B pattern difference, the maximum distance which could be measured is 15,000 meters. An additional pattern frequency would furnish an increment (150,000

meters) greater than the range of the instrument. This is not considered necessary since the distance could be determined within 15,000 meters (10 miles) by map inspection and thereby derive the first digit of the transit time. The table below may be used to determine numerical prefixes to the tellurometer transit time:

Approximate length of line		Numerical prefix
Meters	Miles	
0-15,000	0-10	0
15,000-30,000	10-20	1
30,000-45,000	20-30	2
45,000-60,000	30-40	3

143. Coarse Readings

Coarse readings are obtained during the measurement by reading the graticule on the master cathode ray tube on the A, B, C, and D pattern frequencies. The resolution of the pattern differences to a transit time is discussed in paragraph 155.

144. Fine Readings

a. The electronic circular sweep presentation cannot be centered exactly on the graticule of the cathode ray tube visually. Any error which may be caused by centering errors is corrected by the provision of an A+, A- presentation. The A+ reading is the display of a positive pulse, and the A- reading represents the negative pulse.

b. A further refinement of centering errors is provided through a phase reversal of the A crystal, positive and negative patterns. These are referred to as A+ forward and reverse and A- forward and reverse. This phase reversal is also displayed on the cathode ray tube, and the readings are used to determine a mean fine A+ pattern reading. These displays are comparable to the direct and reverse pointings of the theodolite on an object when measuring angles.

c. Meaning of these fine readings is described in paragraph 153.

Section III. TELLUROMETER OPERATIONS AND COMPUTATIONS

145. Selection of Stations

Electrical line-of-sight is required between the master station and the remote station. In general, it must be nearly optical line-of-sight in that objects, such as hills or mountains, should not block the line-of-sight. However, in some cases a ridge may project as much as 50 feet above the line-of-sight, and a measurement may be made. In artillery survey, the main use of the tellurometer will be to measure distance on a traverse, in which case, angles will be measured with a theodolite. The theodolite will require optical line-of-sight. It would appear that the best site for a tellurometer station is on top of a high peak; however, the following should be taken into consideration, primarily due to effects caused by the reflection of microwaves.

a. The ground between the two stations should be broken, and preferably covered with trees and vegetation to absorb the ground waves and prevent them from interfering with the direct signal.

b. When possible, the ground should slope gradually away from each instrument.

c. If possible, avoid measuring lines over

highly reflective surfaces, i.e., smooth, desert sands and water. Figure 42 illustrates the effect of the reflection of microwaves from water. An error is caused by the tellurometer receiving both the direct wave and the reflected wave, sometimes referred to as ground swing. Some of the error is removed by the method of observing. The mean of the four fine readings, each at a different cavity tune setting, removes a part of the swing error.

d. The instruments should be set well back from the edge of the high land so that as much of the reflective area becomes "dead ground" to the receiving instrument (fig. 42) as possible.

146. Operator Training

a. An instrumentman qualified in the operation of conventional surveying instruments can acquire, in approximately 40 hours, an adequate knowledge of both the master and remote units to perform and supervise all the activities required to complete a field observation and to perform the necessary computations for the determination of a distance.

b. Continued operation of the tellurometer will provide the operator with sufficient knowl-

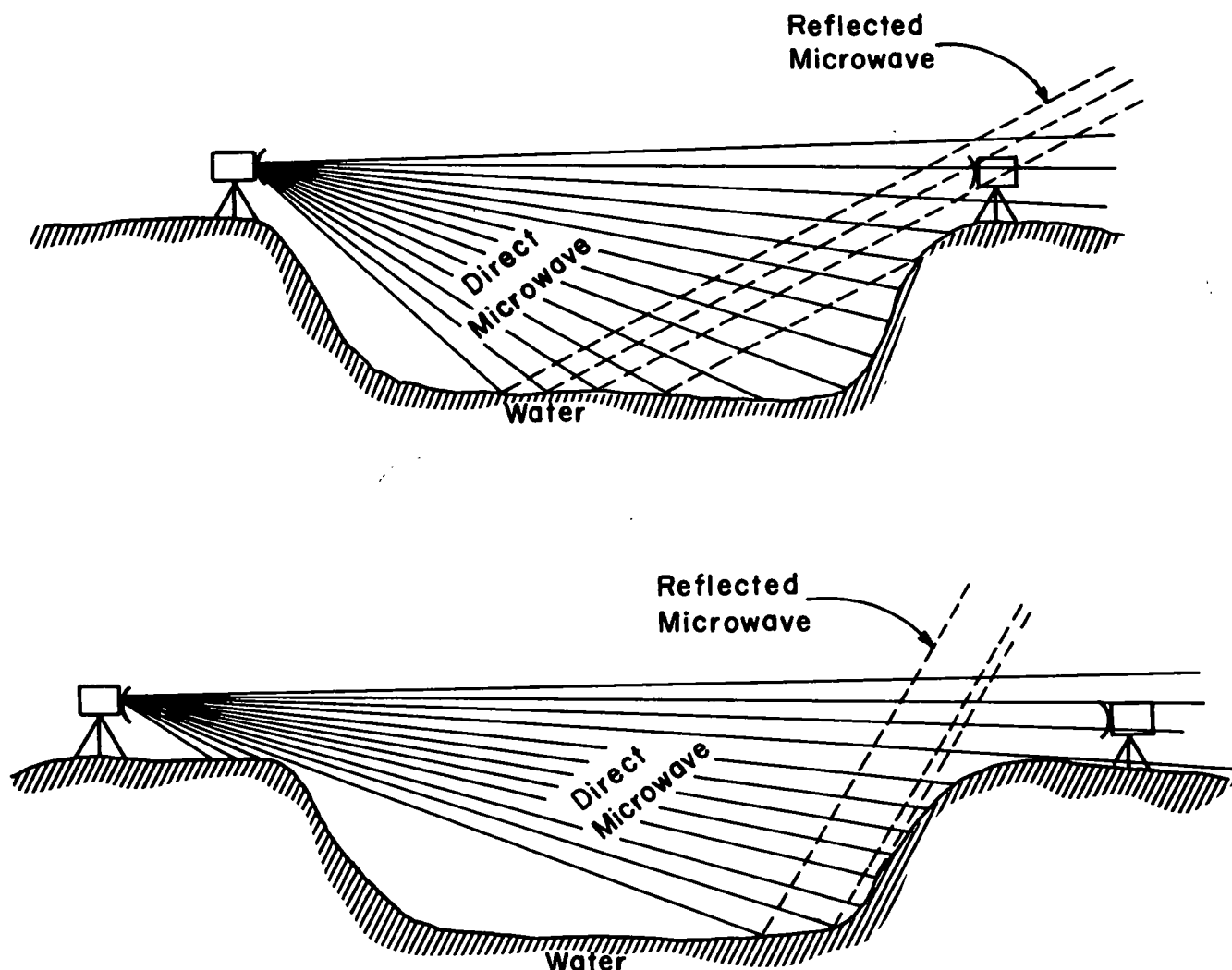


Figure 42. Reflected microwaves.

edge to perform a limited amount of maintenance (par. 163).

147. Instrument Controls

The controls for the operation of the master and remote units are classified in four functional groups—setting up controls for making the master-remote contact, operating controls for making the measurement, monitoring controls for checking the circuit adjustments, and internal controls for preset adjustments of instrumental circuits. The physical location of these controls is shown in figures 38, 39, and 40. The functions of the individual controls in each functional grouping are as follows:

a. Setting Up Controls.

(1) The following controls may be ad-

justed at the *master unit* without establishing contact with the remote unit operator (MEASURE-SPEAK (M/S) key at SPEAK):

Control	Function
BRILLIANCE and FOCUS.	These two controls are adjusted in conjunction with each other to obtain a bright, sharp cathode ray tube (CRT) trace which appears as a luminous spot at this stage.
X SHIFT and Y SHIFT	These two controls are used to center the image at the intersection of the horizontal and vertical diameters of the CRT graticule.

- (2) The following controls are adjusted at the *master unit* after establishing contact with the remote unit (M/S key at MEASURE):

Control	Function
CIRCLE AMPLITUDE	Increases or decreases size of circular trace.
SHAPE and Y AMPLITUDE.	Adjusts for truest circular image.

- (3) The following controls are adjusted at the *remote unit* after contact is established with the master unit (M/S key at MEASURE):

Control	Function
BRILLIANCE, FOCUS X SHIFT, and Y SHIFT.	Same function as in (1) above.

b. Operating Controls.

- (1) The following controls are used at the *master unit* during a distance measurement:

Control	Function
PATTERN SELECTOR	Sets crystal pattern frequencies required for the measurement.
OPERATOR M/S key	Switches to measuring or voice circuit in each unit. Used also as a signaling device during measurements. With the M/S key at MEASURE, the operator may hear but cannot speak to the remote station.
CAVITY TUNE dial	Tunes frequency of klystron carrier wave radiation.
REFLECTOR TUNE dial	Tunes klystron electrically when kept at peak of crystal current during measurements.

- (2) The following controls are used at the *remote unit* during a distance measurement:

Control	Function
PATTERN SELECTOR, M/S key, CAVITY TUNE dial, and REFLECTOR TUNE dial.	Same function as in (1) above.
A+ and A- READING key	Selects the A+ or A- pattern as required during an observation.
FORWARD-REVERSE READING key	Selects the reverse A+ or A- pattern as required.
PULSE AMPLITUDE	Sets amplitude of pulse returned to the master unit. Normally set at 5 unless changed by instructions from the master station.

c. Monitoring Controls.

- (1) The following controls are used at the *master unit* to check the operating circuits prior to making a measurement:

Control	Setting and purpose
SWITCHED METER	Set to REG position to check voltage regulators in klystron circuit. Set to MOD position with M/S key at MEASURE to indicate correct crystal pattern modulation.
CHECK PULSE	Set to AVC position, the meter indicates the signal strength being received. It should always be tuned to maximum.
CHECK PULSE	Pressing this button permits the master unit operator to view on his CRT the pulse pattern presented at the remote CRT.

CRYSTAL CURRENT meter.

Registers crystal current.

- (2) The following controls are used at the *remote unit* to check the operating circuits prior to making a measurement:

Control	Setting and purpose
SWITCHED METER	Same function as in (1) above.
CRYSTAL CURRENT meter.	Same function as in (1) above.

d. Preset Controls.

- (1) The following controls are preset in the *master unit*:

Control	Function
ADJUST MODULATION	Under the ADJUST-MODULATION plate are four slotted controls for the adjustment of each crystal to a specified modulation level. A nonmagnetic screwdriver should be used.
ADJUST FREQUENCY	Under the ADJUST FREQUENCY plate are four controls for the adjustment of crystal frequencies. <i>Synchronization is done only by a qualified technician.</i>
OVEN CYCLE	Heats crystals automatically.

- (2) The following controls are preset in the *remote unit*:

Control	Function
ADJUST MODULATION	Same function as in (1) above.
OVEN CYCLE -----	Same function as in (1) above.

148. Setting up the Tellurometer

Any attempt to operate a master unit and a remote unit while pointing at each other at a distance of 150 meters (500 feet) or less will result in damage to the units. The instructions contained in *a* through *k* below are applicable to both the master station and the remote station:

a. Unstrap the legs of the tripod, loosen the leg clamp thumbscrews, and extend the tripod legs to the desired length; tighten the thumbscrews and embed each leg firmly into the ground, making sure that the tripod head is approximately level and approximately over the point which identifies one end of the distance (line) to be measured. Attach the plumb bob and extend it so that it hangs about 1 inch above the point over which the instrument is to be set up.

b. Remove the instrument from the case and place it on the tripod head. Thread the tripod screw into the base of the instrument and tighten it to insure that the instrument is fixed to the tripod. Point the dipole in the approximate direction of the remote station. The tellurometer radiates a conical beam of about 10°. In windy weather the tellurometer should be tied down to prevent the possibility of the instrument being blown over and damaged.

c. Dismount the parabolic reflector from its closed (travel) position and remount it in the open (operating) position, making sure that fasteners fit properly and snugly. Failure to do so may result in damage to the unit.

d. Remove the power supply cable and the telephone handset from the storage compartment under the control panel. Hang the telephone handset on an improvised hook or bracket on the tripod. Never place the handset on top of the unit, because inaccuracies are created if the handset is left there during the measurement. *Place the low voltage (LT) and the high voltage (HT) switches in the off position.*

e. When a 12-volt battery is used, connect the *short* (8-ft.) 12-volt power supply cable to INPUT. Connect the *red lead to the positive* post and the *black lead to the negative* post.

f. When a 24-volt battery is used, connect the *long* (18-ft.) 24-volt power supply cable to INPUT. Connect the *red lead to the positive* post, and the *black lead to the negative* post. *Do not use the short 12-volt power supply cable with a 24-volt battery*, because this will damage the unit.

g. The system is ready to be turned on after the completion of either *e* or *f* above. Place the *low voltage* (LT) switch in the ON (up) position. This provides a filament current to the tubes in the instrument, and it must be turned on 30 seconds before turning on the high voltage (HT) switch. Both the LT and HT switches must be in the ON position for operation of the instrument. The HT switch should be in the OFF position while waiting for the prearranged time of operation agreed upon by the master and remote operators.

h. Turn the METER SWITCH to the REG (voltage regulator) position and the M/S key to MEASURE. The reading on the SWITCHED METER will vary with the strength of the battery. To permit a satisfactory measurement, the reading should be at least 30. A reading of less than 30 indicates that the charge in the battery is too low for operation.

i. Adjust the REFLECTOR TUNE dial for maximum crystal current. The CRYSTAL CURRENT dial should read above 0.2 for best operation. The lowest reading on the CAVITY TUNE dial will usually give the greatest CRYSTAL CURRENT reading.

j. Turn the METER SWITCH to MOD (modulate) position and check the modulation level of each crystal. The PATTERN SELECTOR must be turned to each crystal, in turn. The correct readings, as viewed on the SWITCHED METER should be 40 on A, B, and C and 36 on D. If these readings are not approximated, remove the ADJUST MODULATION cover and adjust the modulation trimmers. The trimmers should be adjusted if the reading varies ± 2 from 40 or 36, depending on the crystal being checked. A nonmagnetic screwdriver should be used for this adjustment.

k. Switch the M/S key to SPEAK and move the METER SWITCH to the AVC position.

The SWITCHED METER should read about 20 micro-amperes without the two instruments being tuned and without the other set being turned on. Turn the REFLECTOR TUNE dial. If the SWITCHED METER needle moves, the receiver is working. If there is no movement of the indicator, trouble can be suspected in the receiver and a repairman should be consulted.

1. *This step is performed by the master unit only.* Switch the M/S key to SPEAK. There should be a spot of light near the center of the cathode ray tube. Turn the CIRCLE AMPLITUDE control (right side panel) to make this spot as small as possible. Adjust the BRILLIANCE and FOCUS controls (left side panel) for a clear, sharp spot. Center the spot carefully in the graticule, using the X SHIFT and Y SHIFT controls (left side panel).

149. Tuning Procedures

The instrument tuning procedures follow the setting-up procedures and must be completed prior to making a measurement. These procedures start with the M/S key in the SPEAK position and require coordination between the master unit and the remote unit operators. For this reason, the following instructions are arranged to insure that the proper sequence is followed. In each step, the operation designated with the number 1 precedes the operation designated with the number 2.

Meter unit operator

a2. Set the CAVITY TUNE dial two or three numbers below the previously agreed starting number (setting of remote). Place the METER SWITCH in AVC position. Increase the CAVITY TUNE dial setting until a maximum reading is indicated on the SWITCHED METER. A maximum AVC reading at this point indicates that the master instrument is tuned to the remote instrument.

b1. Establish communications with remote operator.

Remote unit operator

a1. Set the CAVITY TUNE dial on the previously agreed starting number. Verify the maximum CRYSTAL CURRENT by using the REFLECTOR TUNE dial.

Place the METER SWITCH in AVC position and watch the SWITCHED METER for a maximum reading as a signal that the master operator has tuned his set.

b2. Answer the master operator's call.

Meter unit operator

c1. Direction find (DF) the instrument by traversing it on the tripod until the SWITCHED METER shows a maximum AVC reading. Check plumb after DF. Instruct the remote operator to direction find his instrument.

d1. Switch to MEASURE and turn the METER SWITCH to MOD position. Check the modulation levels by turning the PATTERN SELECTOR to A, B, C, and D, in turn. Announce each modulation reading to the recorder for entry in block VI of the field record and computations form (fig. 43). Request modulation readings from the remote operator and announce these to the recorder for appropriate entry on the field record and computations form. Turn the METER SWITCH to AVC position.

e1. Announce the following information to the recorder for entry in block I of the field record and computations form (fig. 43): instrument numbers, station numbers, weather conditions, and operator's names.

f1. With the M/S key at MEASURE, adjust the CRT circle to a convenient reading size by using the CIRCLE AMPLITUDE, Y AMPLITUDE and SHAPE controls.

g1. Verify the maximum CRYSTAL CURRENT reading by turning the REFLECTOR TUNE dial. With the METER SWITCH in AVC position, readjust the CAVITY TUNE for a maximum AVC reading on the SWITCHED METER.

Remote unit operator

c2. When instructed to do so, direction find the instrument by traversing it on the tripod until the SWITCHED METER shows a maximum AVC reading. Check plumb after DF.

d2. Switch to MEASURE and turn the METER SWITCH to MOD position. Check the modulation levels by turning the PATTERN SELECTOR to A, B, C, and D, in turn. Note the values of the modulation levels.

When requested to do so, report the modulation readings to the master operator.

e2. Stand by. If requested to do so, provide information to the master operator.

f2. Switch the M/S key to MEASURE and stand by.

g2. If requested to do so, adjust the PULSE AMPLITUDE.

Inspect the circular trace on the CRT for a good clean break.

If a good break cannot be obtained or the pulse appears too weak or too strong, instruct the remote unit operator to adjust the PULSE AMPLITUDE.

Note. The tellurometer system is now ready for distance measuring.

150. Measurement Procedure

A tellurometer measurement consists of one set of initial coarse readings, four sets of fine readings, and one set of final coarse readings. A coarse reading consists of readings on the A+, A-, B, C, and D patterns, and a fine reading consists of readings on the A+, A-, A- reverse, and A+ reverse patterns. All readings are recorded on the field record and computations from (fig. 43) as they are taken. The completed form constitutes a record of the distance determined and the system operation during one measurement. The field record and computations forms for each measurement should be retained to make up a permanent log for the operation of the system. The measuring procedures require coordination between the master unit and remote unit operators. In each step, the operation designated with the number 1 precedes the operation designated with the number 2.

Master unit operator

a1. Switch to SPEAK and advise the remote unit operator that the initial coarse readings will be taken in the prescribed order (A+, A-, B, C, D). Switch to MEASURE, turn the PATTERN SELECTOR to position A, and read the value on the CRT to the nearest division (fig. 41). Announce the value to the recorder for entry in block II of the field record and computations form (fig. 43).

Flick the M/S key twice to indicate to the remote unit operator that the reading of the A+

Remote unit operator

a2. When instructed that the initial coarse readings will start, switch to MEASURE. Each time the master unit operator signals by flicking the key, switch to the next pattern frequency.

The master unit operator's signal will appear as a flick on the remote unit CRT and as a break in the measuring tone on the phone.

pattern is complete and that a reading is desired on the next (A-) pattern.

When the A- pattern appears on the CRT, read the value and announce it to the recorder for entry in block II of the field record and computations form.

For the A- pattern, continue to read the clockwise edge of the break.

Flick the M/S key twice to indicate to the remote unit operator that the reading of the A- pattern is complete and that a reading is desired on the next (B) pattern.

Turn the PATTERN SELECTOR to position B and proceed as with the previous readings. After each reading, flick the switch to indicate readiness to read the next pattern.

When the C and D pattern readings have been completed, return the PATTERN SELECTOR to position A. This completes the initial coarse readings.

b1. Switch to SPEAK and advise the remote unit operator that each fine reading will be taken in prescribed order (A+, A-, A- reverse, A+ reverse). Normally four sets of fine readings are taken. The frequency interval between sets should be the maximum allowable (i.e., 3, 5, 7, and 9) over the range of the CAVITY TUNE dial. When making the reverse readings, continue to read the clockwise leading edge of the break.

Announce to the remote unit operator the remainder of the CAVITY TUNE dial settings.

b2. Switch to SPEAK and wait for instructions.

When advised that fine readings will be taken, turn the METER SWITCH to AVC position and set the CAVITY TUNE dial to the announced setting.

The CAVITY TUNE dial setting should be the same as that on which the initial coarse readings were taken.

c1. Adjust the CAVITY TUNE dial, if necessary, for maximum AVC readings. Check the REFLECTOR TUNE dial for maximum CRYSTAL CURRENT. Announce "measure" to the remote unit operator and switch to MEASURE.

Check the circle sweep for focus, brilliance, size, shape, and circle break. If the circle break is not apparent, adjust it with the REFLECTOR TUNE dial. If the adjustment fails to produce a break, communicate with the remote unit operator and request a high PULSE AMPLITUDE setting.

d1. Take the four sets of fine readings at the previously announced CAVITY TUNE dial intervals. Flick the M/S key to signal the remote unit operator.

Announce the value read for each pattern during the measurement of each set to the recorder for entry in block III of the field record and computations form (fig. 43):

After taking the A+ reverse reading of each set, the master unit operator should pause momentarily before proceeding and allow the recorder to check the recorded values for possible reading errors.

e1. Switch to SPEAK and advise the remote unit operator that final coarse readings will be taken.

c2. When instructed to do so, increase or decrease the PULSE AMPLITUDE.

d2. For each of the four sets of fine readings, use the following procedure:

When signaled by the master unit operator that the A+ reading is complete, switch the PATTERN SELECTOR to the A- position. On the second signal from the master unit operator, depress the FORWARD-REVERSE key. When the FORWARD-REVERSE key is in the REVERSE position, the master unit operator reads the A- reverse pattern. On the third signal, switch the PATTERN SELECTOR to the A+ position. This presents the A+ reverse pattern to the master unit operator. On the fourth signal, raise the FORWARD-REVERSE key and wait for instructions. When instructed to do so, switch to SPEAK and advance the CAVITY TUNE dial to the next setting.

e2. Follow the procedure in a2 above at the last CAVITY TUNE dial setting.

Follow the procedure in a1 above at the last CAVITY TUNE dial setting. As the readings are made, announce the values to the recorder for entry in block IV of the field record and computations form (fig 43).

f1. Compare the interpreted initial and final coarse readings for agreement (blocks II and IV of the field record and computations form).

If a significant disagreement is evident (par. 154), take additional coarse readings until the error is isolated.

g1. Advise the remote unit operator that the measurement is complete and give further instructions.

Instructions must be explicit and thoroughly understood, since at this point the instruments will be turned off and communications severed.

If at any time in tuning to a new CAVITY TUNE dial setting, communications cannot be made with the remote unit, return to the last CAVITY TUNE dial setting at which contact was made and issue instructions.

f2. Stand by.

g2. Proceed as instructed.

If at any time in tuning to a new CAVITY TUNE dial setting communications cannot be made with the master unit, return to the last CAVITY TUNE dial setting at which contact was made and await instructions.

151. Computing a Tellurometer Distance Measurement

a. Computations required for a tellurometer distance measurement are performed in the following order:

- (1) Interpreting initial coarse readings.
- (2) Interpreting fine readings.
- (3) Interpreting final coarse readings.
- (4) Resolving a transit time in millimicroseconds from correctly interpreted pattern differences.
- (5) Computing a slope distance in meters from a transit time in millimicroseconds.

FIELD RECORD AND COMPUTATIONS - TELLUROMETER															
(TB ENG 23)															
BLOCK I - STATION DATA															
STATION		HEIGHT METERS		INST. NO.		OPERATOR		WEATHER: <i>Clear - Warm</i>							
MASTER: <i>Sterling</i>		1 <i>449.1</i>		238		<i>Healy</i>		RECORDER: <i>Nisbett</i>							
REMOTE: <i>Apache</i>		2 <i>412.6</i>		339		<i>West</i>		APPROX. DIS.: MILES 2.3		METERS 3500					
3		HEIGHT DIFF. (1) & (2) <i>36.5</i>		4		SUM OF HEIGHTS (1) & (2) <i>861.7</i>		5		MEAN HEIGHT (4) ÷ (2) <i>430.8</i>					
BLOCK II - INITIAL COARSE READINGS							BLOCK IV - FINAL COARSE READINGS								
A+	<i>05</i>	A+	<i>05</i>	A+	<i>05</i>	A+	<i>05</i>	A+	<i>07</i>	A+	<i>07</i>	A+	<i>07</i>		
B	<i>78</i>	C	<i>65</i>	D	<i>24</i>	A-	<i>99</i>	B	<i>79</i>	C	<i>66</i>	D	<i>25</i>		
DIFF	<i>27</i>	DIFF	<i>40</i>	DIFF	<i>81</i>	DIFF	<i>06</i>	DIFF	<i>28</i>	DIFF	<i>41</i>	DIFF	<i>82</i>		
COMPARE WITH A+ <i>03.0</i>							COMPARE WITH A+ <i>04.0</i>								
BLOCK III - FINE READINGS							BLOCK V - TRANSIT TIME (III, IV & X)								
SET	REMOTE DIAL	A	FORWARD	REVERSE	MEAN DIFF		APPROX DIS MILES (X)		0 0 0 0 0 0 0 0						
1	+	<i>05</i>	<i>59</i>				FINAL } A+, B DIFF		2 0 0 0 0 0						
	3	-	<i>99</i>	<i>51</i>			COARSE } A+, C DIFF		4 1 0 0 0 0						
	DIFF	<i>06</i>	<i>08</i>	<i>14</i>	<i>7.0</i>		READING } A+, D DIFF		8 2 0 0 0						
2	+	<i>09</i>	<i>57</i>				MEAN FINE READING III		0 3 3 1						
	5	-	<i>02</i>	<i>50</i>			BRING DOWN UNRESOLVED TRANSIT TIME		0 2 4 8 0 3 3 1						
	DIFF	<i>07</i>	<i>07</i>	<i>14</i>	<i>7.0</i>		RESOLVED TRANSIT TIME		0 2 3 8 0 3 3 1						
3	+	<i>08</i>	<i>56</i>												
	7	-	<i>03</i>	<i>51</i>											
	DIFF	<i>05</i>	<i>05</i>	<i>10</i>	<i>5.0</i>										
4	+	<i>07</i>	<i>59</i>												
	9	-	<i>99</i>	<i>50</i>											
	DIFF	<i>08</i>	<i>09</i>	<i>17</i>	<i>7.5</i>										
SUM MEAN DIFF					<i>26.5</i>										
DIVIDE BY NUMBER OF SETS TIMES 2					<i>3.31</i>										
MEAN FINE READING (COMPARE WITH A+)					<i>3.31</i>										
BLOCK VII - SLOPE DISTANCE, METERS							BLOCK VI - METER READINGS								
1	LOG CORRECTED TRANSIT TIME (IV)			<i>4 376 6373</i>		AVC		<i>50</i>		MASTER		<i>48</i>			
2	LOG 1/2 V/N METERS			<i>9 175 6509</i>		REGULATOR		<i>50</i>		REMOTE		<i>55</i>			
3	LOG SLOPE DISTANCE METERS (I) & (2)			<i>3 552 2882</i>		MODULATION		A <i>40</i>		A		<i>40</i>			
						B <i>39</i>		B		B		<i>40</i>			
						C <i>41</i>		C		C		<i>39</i>			
						D <i>36</i>		D		D		<i>36</i>			
BLOCK VIII - VERTICAL ANGLE							BLOCK IX - SEA LEVEL DISTANCE METERS								
							1 LOG SLOPE DISTANCE METERS (VII)							<i>3 552 2882</i>	
							2 LOG COS VERTICAL ANGLE (VIII)							<i>9 999 9773</i>	
							3 ((1)+(2)) LOG HORIZONTAL DISTANCE METERS							<i>3 552 2655</i>	
							4 LOG SEA LEVEL COEFFICIENT (IX)							<i>9 999 9727</i>	
							5 ((3)+(4)) LOG SEA LEVEL DISTANCE METERS							<i>3 552 2382</i>	
							6 SEA LEVEL DISTANCE METERS							<i>3566.47</i>	
BLOCK X - FIRST FIGURE (TRANSIT TIME)															
1 DIFFERENCE HEIGHT METERS <i>36.5</i>							APPROX DISTANCE MILES (I)							FIRST FIGURE	
2 LOG (1)							<i>0-10</i>							<i>0</i>	
3 LOG SLOPE DISTANCE METERS (VII)							<i>10-20</i>							<i>1</i>	
4 ((2)-(3)) LOG SIN VERT ANGLE							<i>20-30</i>							<i>2</i>	
5 VERTICAL ANGLE EQUAL TO LOG SIN (4)							<i>30-40</i>							<i>3</i>	
COMPUTER				CHECKER				SHEET				OF SHEETS			
NOTEBOOK REFERENCE				AREA				DATE							

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Figure 43. Field record and computations form.

BLOCK XI - SEA LEVEL COEFFICIENT

The height used to determine log sea level coefficient is height of known station to the nearest 100 meters. Mean height should be used if the heights of both stations are known.

HEIGHT METERS	LOG SEA LEVEL COEFFICIENT
-100	0.0000068
-50	0.0000034
00	0.0000000
50	9.9999966
100	9.9999931
200	9.9999863
300	9.9999795
400	9.9999727
500	9.9999659
600	9.9999590
700	9.9999522
800	9.9999453
900	9.9999386
1000	9.9999317
1100	9.9999249
1200	9.9999181
1300	9.9999112
1400	9.9999044
1500	9.9998976
1600	9.9998908
1700	9.9998839
1800	9.9998770
1900	9.9998703
2000	9.9998634
2100	9.9998566
2200	9.9998498
2300	9.9998429
2400	9.9998361
2500	9.9998292
2600	9.9998225
2700	9.9998156
2800	9.9998088
2900	9.9998020
3000	9.9997951
3100	9.9997883
3200	9.9997815
3300	9.9997747
3400	9.9997678
3500	9.9997609
3600	9.9997542

NOTE:

The above values were computed for a northing of 3 200 000 and azimuth of 45 degrees and can be used anywhere on the UTM grid without causing an error greater than 1:250,000.

GIVEN:

Height of station - METERS.

FIELD DATA:

- Approximate distance in both miles and meters.
- Corrected transit time.
- Height if not available.
- Vertical angle (*compute if not possible to measure*).

GUIDE:

- BLOCKS II, III & IV - If A+ is less than B, C or A-, add 100 to A+ before determining the difference.
- BLOCKS II, III & IV - "Compare with A+" means that this figure must compare ± 4 MUS with A+ in the final coarse reading. If necessary add 50.
- BLOCK VIII (5) - Measured or computed vertical angle.

LIMITATIONS:

This form may be used for obtaining artillery survey accuracies.

RESULTS:

A sea level distance is determined which should be treated the same as a taped distance.

Figure 44. Back of field record and computations form.

(6) Reducing a slope distance to a horizontal and sea level distance in meters.

b. Tellurometer distance measurements are normally computed at the master station before party personnel depart for subsequent survey operations. This permits the verification of the distance determined by map scaling and the resolution of ambiguous pattern differences if they occur. Figure 43 illustrates recording of readings on a field record and computations form and is used as a reference for the discussions on computations.

152. Interpreting the Initial Coarse Readings (Block II)

a. The phase difference is determined by subtracting the coarse readings, B, C, D, and A— from the A+ reading. If necessary, add 100 to A+ before subtracting. In figure 43, it is necessary to add 100 to A+.

b. Divide the A+ A— difference by 2. Compare this value (03.0) with the A+ reading (05). They compare within 2 millimicroseconds, which is satisfactory. If the readings do not compare within 4 millimicroseconds, they must be reobserved. After dividing by 2, in some cases, it will be necessary to add 50 when making the A+ comparison.

153. Interpreting the Fine Readings (Block III)

In the example below, one set of the fine readings in figure 43, block III, are meant:

Set	Remote dial	Forward	Reverse
1	3	A+ 05 A— 99 06	A+ 59 A— 51 08

$06 + 08 = 14 \div 2 = 07$ mean difference

$07 \div 2 = 3.50$ mean fine reading

A+ (initial coarse) = 05.00 (block II)

Mean fine reading = 03.50

Zeroing error = 1.50 millimicroseconds

a. In the *forward readings*, the A— is subtracted from the A+. Because the A+ was smaller than the A—, it was necessary to add 100 to 05 before subtracting ($100 + 05 = 105$, $105 - 99 = 06$). Add 100 only when necessary.

b. In the *reverse readings*, the A— is subtracted from the A+ ($59 - 51 = 08$). If the A+ had been smaller than the A—, it would

have been necessary to add 100 to the A+ before subtracting.

c. The difference in the forward readings is added to the difference in the reverse readings, and the sum is divided by 2 to obtain the mean difference ($06 + 08 = 14 \div 2 = 07$).

d. The mean difference is divided by 2 to obtain the mean fine reading ($07 \div 2 = 3.50$).

e. Subparagraphs a through d above correct for the zeroing error (par. 144). The three remaining fine readings which were taken at remote dial settings 5, 7, and 9 are meant the same as the example above which was taken at remote dial setting 3. The mean fine reading for the four sets of fine readings (3.31) is determined and compared with A+ (03.00) in block II ($3.31 - 3.00 = 0.31$). This comparison is satisfactory because it is within 4 millimicroseconds.

f. Four sets of fine readings are made using all parts of the cavity tune dial; i.e., 3, 5, 7, and 9. The use of all parts of the cavity tune dial will reduce the reflection error until it is so small that it will seldom affect artillery survey accuracies.

154. Interpreting the Final Coarse Readings (Block IV)

The final set of coarse readings is taken primarily as a check on the initial coarse readings. The final coarse readings are interpreted and the differences are resolved in the same manner as the initial coarse readings (par. 152). If the difference between the patterns of the two sets of coarse readings exceed that shown below, a third set of coarse readings is taken and the differences are resolved.

Pattern	Maximum difference
A	4
B	3
C	3
D	2

155. Resolving the Transit Time from Pattern Differences (Block V)

a. In the spaces provided in block V, transit time (fig. 43), enter the *final coarse readings (differences)* from block IV, the mean fine reading (to the nearest hundredth) from block III, and the first figure (transit time) from block X (approximate distance in miles).

c. Determine the resolved transit time by successive comparison and enter the value on the line for resolved transit time (fig. 43). The method used to resolve a corrected transit time is illustrated in figure 45. The resolved transit time represents the travel time in millimicroseconds of the electromagnetic wave transmitted from the master unit to the remote unit and return.

a. The resolved transit time in millimicroseconds is a time measurement which must be corrected for the refraction of atmosphere and converted to a one-way slope distance in meters. The log of the resolved transit time is entered in line 2 of block VII.

the procedure and eliminates the requirement for meteorological observations during a measurement. This index has been corrected mathematically by applying the velocity of a radio wave per millimicrosecond to provide a constant, the log of which is added to the log of the resolved transit time to produce the log of a one-way slope distance in meters. This log (9.1756509) appears on line 2, block VII (fig. 43) and is added to the log on line 1; the resulting sum is the log slope distance in meters (line 3, block VII).

c. The log of one-half the corrected refractive index (9.1756509) block VII, line 2 should provide an accuracy greater than 1:10,000 at air temperatures of -40° F. to $+120^{\circ}$ F. at elevations of $-1,000$ to $+10,000$ feet, and at all conditions of humidity. One-half the corrected refractive index is used because it is multiplied by the transit time of master to remote to master which is twice the distance from master to remote.

Obtained from approximate distance in miles (block I)		0	0	0	0	0	0	0	From block I, enter 0 on line for resolved transit time (Approx. dis. miles from map scale = 2.3 miles)
Finol	A + B Diff	2	8	0	0	0	0	0	To compare with A + B Diff consider $\begin{matrix} \nearrow 33803.31 \\ \rightarrow 23803.31 \\ \searrow 13803.31 \end{matrix} = \left(\begin{array}{l} \text{value closest to 28000;} \\ \text{enter 2 on line for} \\ \text{resolved transit time} \end{array} \right)$
Coorse	A + C Diff	4	1	0	0	0	0	0	To compare with A + C Diff consider $\begin{matrix} \nearrow 5803.31 \\ \rightarrow 4803.31 \\ \searrow 3803.31 \end{matrix} = \left(\begin{array}{l} \text{value closest to 4100;} \\ \text{enter 3 on line for} \\ \text{resolved transit time} \end{array} \right)$
Readings (block IV)	A + D Diff	8	2	0	0	0	0	0	To compare with A + D Diff consider $\begin{matrix} \nearrow 903.31 \\ \rightarrow 803.31 \\ \searrow 703.31 \end{matrix} = \left(\begin{array}{l} \text{value closest to 820;} \\ \text{enter 8 on line for} \\ \text{resolved transit time} \end{array} \right)$
Mean fine reading (block III)					0	3	3	1	Use this value to compare with A + D Diff
Unresolved transit time (block III)		0	2	4	8	0	3	3	1
Resolved transit time (block III)		0	2	3	8	0	3	3	1

157. Determination of the Vertical Angle (Block VIII)

a. The slope distance has been determined in block VII. The horizontal distance is used in artillery survey. Consider that the slope distance is the hypotenuse of a right triangle. The horizontal distance may be computed using the slope distance and the vertical angle or the slope distance and the difference in height (block VIII).

b. When the vertical angle is measured, it is entered on line 5 (fig. 43). The vertical angle should be measured reciprocally or corrected for curvature, when measuring over a long distance. The vertical angle may be expressed in either degrees, minutes and seconds, or it may be expressed in mils, depending on the type of theodolite used to make the measurement.

c. If the vertical angle is not measured, then it must be computed by using the slope distance and the difference in height. The difference in height is obtained from block I, line 3. The vertical angle is computed in block VIII.

d. The heights of the master station and the remote station are entered in block I, line 1 and 2. The height is obtained from known data or determined with the altimeter (ch. 12).

158. Reduction of Slope Distance to Sea Level Distance (Block IX)

a. The slope distance is reduced to sea level distance by computations, using the slope distance, vertical angle and sea level coefficient. The computations are made by following the instruction in block IX (fig. 43).

b. Instructions for the use of the sea level coefficient are on the back of the form in block XI (fig. 44).

c. The computations on the field record and computations form (fig. 43) end with sea level distance in block IX. To carry the computations further would be a duplication of effort, since most Department of the Army artillery survey forms provide for the application of the log scale factor to convert to universal transverse mercator (UTM) grid distance.

d. When a tape is used for determining distance in artillery survey the distance taped is horizontal distance when using a tape. These taped distances are relatively short and the

method used in taping is not sufficiently accurate to warrant converting to sea level distance. However, a distance determined with the tellurometer is of a greater length and of sufficient accuracy for conversion to sea level distance rather than horizontal distance at the height at which the measurement was made.

159. Survey Party Personnel and Duties

a. One man can operate either the master or remote unit. However, in order to fully utilize the accuracy and speed of a tellurometer survey, two men—an instrument operator and a recorder—are required for each unit. As with all artillery survey operations, two independent computations must be made.

b. The theodolite will be used for angle measurement with the tellurometer. Generally, the tellurometer is used in artillery fourth-order survey in which case fourth-order specifications will be used. If used for artillery fifth-order survey the tellurometer distances are measured the same as for artillery fourth-order, and artillery fifth-order specifications are used for angle measurement. In either case one theodolite is provided with each master and remote unit. An altimeter is also provided with each master and remote unit for the determination of height when a vertical angle cannot be measured.

c. The tripod should be set up over the station and used for both the tellurometer and the theodolite. The same instrument man and recorder utilized for distance measurements are utilized for angle measurements.

160. Tellurometer Traverse

a. The primary use of the tellurometer in artillery survey is to measure distance for traverse. However, any required distance varying in length from 150 meters to approximately 40 miles may be measured. The main advantages of determining distance by tellurometer over taping are greater accuracy, measurement over rough terrain, and the relatively short time required to measure long distances.

b. Short distances can usually be determined in less time with a tape than with the tellurometer. The average distance measured in a tellurometer traverse will be from 2 to 5 miles, because of the necessity of distributing survey control throughout an area of operation.

c. A set of tellurometer equipment consists of one master unit and two remote units. In traverse, the master station is the mid-station and the remote units are located at the forward and rear stations. The master unit measures the distance to the forward and to the rear station each time it is set up. The leapfrog method is used for the extension of survey control. Angles are measured at each tellurometer station. When measurements are complete at the first three stations, the master station and rear remote station are moved to the next successive points (fourth and fifth points, respectively). The former forward remote station remains in position and on succeeding measurements acts as rear remote station. The procedure is continued with the master station being positioned between two remote stations until measurements are completed.

161. Trilateration

a. Trilateration (the measurement of three sides of a triangle to solve for three angles as opposed to measuring three angles with a known baseline in triangulation) is another

method of survey for which the tellurometer may be used.

b. Generally, trilateration will not be used when a tellurometer traverse could be used to establish survey control, because, in most tactical situations and terrain, a tellurometer traverse is more accurate, is faster, is less complicated, and requires fewer computations and less reconnaissance. Vertical control cannot be carried in trilateration, except with the altimeter.

c. However, trilateration is a method of survey which may be used when no other method can be used. If the area is covered with heavy ground fog, angles cannot be measured with a theodolite; thus, a tellurometer traverse cannot be used to establish survey control. If a line of known direction is available, it may be used as one side of a triangle, and the other sides of the triangle could be measured with the tellurometer to establish a point by trilateration. Height to the point could be determined with the altimeter and an azimuth provided with an artillery gyro azimuth surveying instrument.

Section IV. TELLUROMETER MAINTENANCE

162. General

a. Discretion must be exercised in assigning maintenance responsibilities to operating personnel. The availability of artillery surveyors with a sufficient knowledge of electronics to perform all of the tellurometer adjustments and repairs is limited. For this reason, the operator's maintenance should be confined to a level suitable for personnel accustomed to conventional survey equipment.

b. The tellurometer is a relatively delicate instrument. Unlike conventional survey equipment, the tellurometer is susceptible to many effects besides rough handling. The tellurom-

eter generates a 250-volt potential at the Klystron cavity. *Power to the unit must be turned off before removing the side panels. Maintenance experimentation by operating personnel must be strictly prohibited.*

163. Equipment Failures and Remedial Actions

a. The following chart has been prepared principally as an aid to maintenance instruction and is a *guide only*. It is not intended to supplant maintenance directives. For maintenance responsibilities and procedures, refer to TB ENG 23, Use of The Tellurometer in Military Surveying.

Failure	Probable cause	Remedy	Level
Power supply:			
No power to unit.	Power connection broken.	Connect	Operator.
	Blown or corroded fuses.	Replace or clean.	Operator.
	Battery clips broken or corroded.	Replace or clean.	Operator.

Failure	Probable cause	Remedy	Level
Power supply—Continued	Vibrator out -----	Report to second-echelon repairman.	Second echelon.
	Battery dead -----	Replace -----	Operator.
Sparkling at powerpack.	Broken cable or cable shield.	Report to second-echelon repairman.	Second echelon.
Switched meter:			
No REG indication.	No power or internal failure.	Check power as above; if power supply is satisfactory, report to second-echelon repairman.	Operator. Second echelon.
REG too high; needle remains above scale.	Defective power cable shield.	Report to second-echelon repairman.	Second echelon.
Crystal current meter:			
No registration.	Defective antenna diode.	Tap diode crystal lightly or replace.	Operator.
	Defective current meter.	Report to second-echelon repairman.	Second echelon.
Excessive current on all cavity tune frequencies.	Antenna reflector still in traveling position.	Place in operating position.	Operator.
Current below 0.15 ma at all frequencies.	Low battery -----	Replace -----	Operator.
	Maladjusted dipole.	Report to second-echelon repairman.	Second echelon.
	Impaired reflector tune control (if CRT trace jumps when control is moved).	Report to second-echelon repairman.	Second echelon.
Current low on one frequency.	Maladjusted klystron.	Report to second-echelon repairman.	Second echelon.
	Maladjusted dipole.	Report to second-echelon repairman.	Second echelon.
No change in meter when cavity tuner is turned.	Screws loose on shaft from knob to tuner.	Report to second-echelon repairman.	Second echelon.
Cathode ray tube:			
Brilliance too dim or none at all, but signal can be heard on phone.	Brilliance setting too low.	Turn higher -----	Operator.
	Faulty cathode ray tube.	Report to second-echelon repairman.	Second echelon.
	Improperly seated cathode ray tube.	Report to second-echelon repairman.	Second echelon.
	Burned out filament in cathode ray tube.	Report to second-echelon repairman.	Second echelon.

Failure	Probable cause	Remedy	Level
Cathode ray tube — Continued	Incorrect pulse amplitude setting.	Check pulse at remote unit.	Operator.
No circle break, but signal tone on phone with normal traces on cathode ray tube of each unit.	Master unit not properly tuned to remote unit. (Tuned to a side frequency.)	Flick MEASURE-SPEAK switch; note AVC reading. If appreciable change occurs, improper tuning denoted.	Operator.
	Too high brilliance setting.	Reduce brilliance.	Operator.
	Faulty tubes in IF, limiter or discriminator.	Report to second-echelon repairman.	Second echelon.
	Faulty diodes in limiter output.	Report to second-echelon repairman.	Second echelon.
	Broken lead in discriminator.	Report to second-echelon repairman.	Second echelon.
Unsteady circle.	Klystron not securely seated.	Report to second-echelon repairman.	Second echelon.
	Moving objects in path of beam.	Await cessation.	Operator.
No circle on master unit cathode ray tube.	OPERATOR MEASURE-SPEAK switch on SPEAK at either station.	Set switch to MEASURE.	Operator.
	Incorrect cavity tuning.	Check at both stations.	Operator.
Distorted circle on master unit cathode ray tube.	Master unit tuned to harmonic.	Check modulation.	Operator.
	Maladjusted shape control.	Adjust -----	Operator.
	Defective X or Y amplifier tube.	Report to second-echelon repairman.	Second echelon.
No circle at one crystal setting.	Defective crystal on master or remote unit.	Switch to MEASURE. Switch to MOD. If no MOD reading, crystal is defective.	Second echelon.
	Defective oscillator tube in circuit.	Report to second-echelon repairman.	Second echelon.
Different circle sizes at different crystal settings.	Incorrect crystal frequency modulation.	Adjust: A = 40, B = 40, C = 40, D = 36.	Operator.

Failure	Probable cause	Remedy	Level
Cathode ray tube — Continued	Low battery-----	Check REG. Recharge.	Operator.
Small circle not reacting to amplitude control.	Faulty diode in modulation circuit.	Report to second-echelon repairman.	Second echelon.
Different break presentation at different crystal settings.	Incorrect crystal synchronization.	Paragraph 163b.	Operator.
Radiotelephone:			
No measuring tone.	Faulty connection-----	Report to second-echelon repairman.	Second echelon.
	OPERATOR MEASURE-SPEAK switch at MEASURE, either unit.	Set switch to SPEAK.	Operator.
	Incorrect crystal modulation setting.	Adjust: A = 40, B = 40, C = 40, D = 36.	Operator.
No measuring tone.	Defective crystal -----	Report to second-echelon repairman.	Second echelon.
No communication.	Units improperly pointed.	Direction find.	Operator.
	Faulty telephone connection.	Report to second-echelon repairman.	Second echelon.
	OPERATOR MEASURE-SPEAK switch at MEASURE.		
Large A+ A- spread:	Master unit cathode ray tube trace incorrectly centered.	Adjust -----	Operator.
	Defective klystron, when condition appears suddenly.	Report to second-echelon repairman.	Second echelon.
	Defective capacitor in deflection circuit.	Report to second-echelon repairman.	Second echelon.

b. When adjusting for SHAPE and Y AMPLITUDE, if it is impossible to obtain a circular image on the master cathode ray tube, the crystal will have to be synchronized. Each crystal in the master unit is synchronized with the corresponding crystal in the remote unit. When a circular image on the CRT cannot be obtained, switch to other crystals. If a satisfactory circular image is obtained on the other crystals, it is necessary to synchronize the crystal which will not provide a circular image. This must be done by a qualified technician.

The following procedure is used to synchronize a crystal:

(1) *Master unit.*

- (a) Assume that the A crystal requires synchronization. Switch to SPEAK and instruct the remote operator to synchronize the A crystal.
- (b) When the remote operator acknowledges, switch to MEASURE. Set the PATTERN SWITCH to the A crystal. *Do not remove the plastic cover marked ADJUST FREQUENCY on the master unit.*

(2) *Remote unit.*

- (a) Switch to SPEAK, acknowledge the master operator's instructions, and request him to switch to the A crystal.
- (b) Remove the plastic cover marked ADJUST FREQUENCY and the right side cover to expose the SET CRYSTAL BUTTON on the remote unit.
- (c) Hold in the spring loaded SET CRYSTAL BUTTON and adjust the A+ crystal screw to obtain a relatively stationary elliptical trace on the CRT. This trace may have some motion, but it should not appear as a rapidly moving basket weave. A nonmagnetic screwdriver should be used.
- (d) Repeat synchronization for the A— crystal.
- (e) Repeat synchronization for other crystals B, C, or D as required.
- (f) Notify the master unit operator when synchronization is complete.

164. Notekeeping

Field notes of the tellurometer are entered on DA Form 5-139 (Field Record and Computa-

tions—Tellurometer). The computations for determining sea level distance are also accomplished on this form. The completed form with field records and computations should be filed with the survey computation where the distance was utilized.

165. Operating Temperature

a. The tellurometer has been designed to operate over the range of -40° F. to $+104^{\circ}$ F. air temperature. The crystals of both the master and remote units are mounted in an oven which automatically maintains operating temperature. The oven begins operation as soon as the power source is connected, regardless of whether the low voltage (LT) or the high voltage (HT) is on or off.

b. Readings should not be taken until the OVEN CYCLE lamp has gone off for the first time. The OVEN CYCLE lamp will then blink on and off while automatically maintaining operating temperature.

c. Approximately 30 minutes is required for the crystals to reach operating temperature at -40° F. air temperature; less than 15 minutes is required, at $+40^{\circ}$ F. air temperature. If the tellurometer is operated in cold, extremely windy weather, a light windbreak around the instrument will reduce warmup time.

CHAPTER 10

TARGET SET, SURVEYING

Section I. GENERAL

166. General

a. The target set is used by artillery missile firing batteries, which require a very accurate laying azimuth, to mark one end of the orienting line. The target set is not used for artillery survey.

b. The target is mounted on a tripod. The tripod is the same type of tripod used with the T2 or T16 theodolite. The carrying case (12 x 10 x 6 inches) is a wooden, top-opening box which contains two targets, two tribrachs, and two night light attachments. Two tripods with plumb bob and adjusting wrench and two battery cases are issued with the target set.

167. Setting up the Tripod

The procedures used for setting up the tripod for the theodolite are also used for setting up the tripod for the target set.

168. Placing the Target on the Tripod

The tribrach is fastened to the tripod with

the instrument holding screw. The target is fastened to the tribrach with the instrument sliding clamp located on the side of the tribrach.

169. Leveling and Pointing the Target

a. The target tribrach contains three leveling screws, the optical plumb, and a circular level vial. The target contains a longitudinal level vial and is leveled and plumbed over the point in the same manner as the theodolite (pars. 91 and 92).

b. The target is oriented perpendicular to the line-of-sight of the instrument which is pointing on the target.

170. Illumination of Target

The night light is attached to the back of the target and is plugged into the battery case. The battery case is the same as that used for the theodolite.

Section II. USE AND CARE OF THE TARGET

171. Sighting the Target

a. A sighting (pointing) is made on the target by bisecting the extended apex of the large triangle with the vertical crossline and bisecting the extended vertexes of the two smaller triangles with the horizontal crossline (fig. 46).

b. The distance from the angle measuring instrument to the target should be approximately the same distance as from the angle measuring instrument to the object to which the angle is measured. The focus of the tele-

scope should not be changed during the angle measurement.

172. Use of the Target on Short Sightings

In providing an azimuth for an orienting line in terrain which requires short sightings, greater accuracy is obtained by using targets instead of range poles to mark stations. A target is placed over the forward and rear stations. The tribrachs remain with the tripods. The theodolite and targets are moved after each angle is measured. The target on the for-

ward station is replaced with the theodolite. The theodolite is replaced with the rear station target. A target is placed over the new forward station. This leapfrog procedure provides greater accuracy in centering and leveling on short lines, but little is gained on long lines.

173. Adjustments of the Target

The target requires two adjustments—the longitudinal level and the optical plummet adjustments.

a. The longitudinal level is adjusted in the same manner as the plate level on the theodolite (par. 103).

b. The optical plummet is adjusted in the same manner as the optical plummet on the theodolite (par. 104).

174. Care and Maintenance of the Target

The target is a precise instrument and should receive the same care and maintenance as the theodolite.

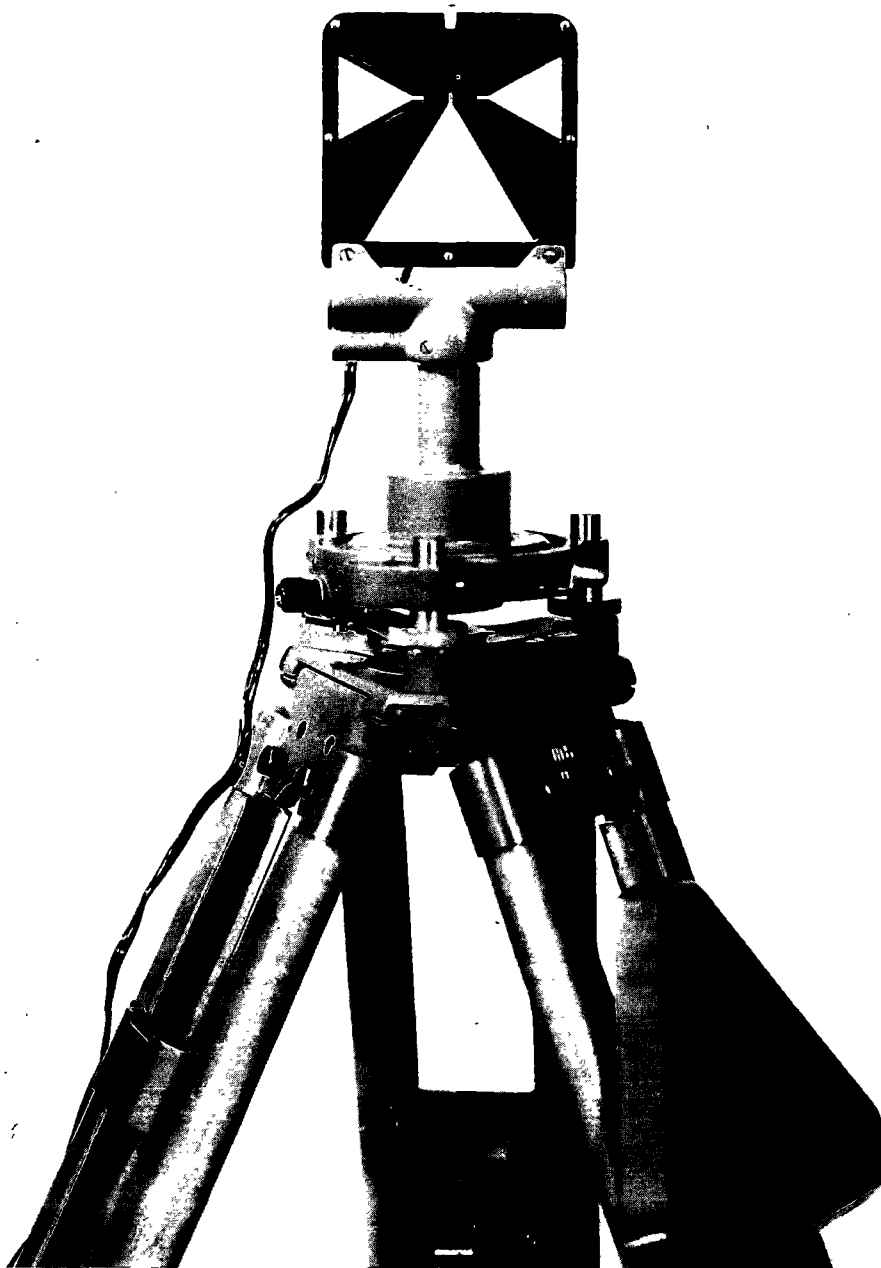


Figure 46. Tripod mounted target.

CHAPTER 11

ARTILLERY GYRO AZIMUTH SURVEYING INSTRUMENT

Section I. GENERAL

175. General

The artillery gyro azimuth surveying instrument is a portable gyrocompass used to determine astronomic (true) direction at a fixed position. Direction is determined by observing the effect of the rotation of the earth on the gyroscope and applying appropriate corrections to the instrument. Accuracy of a direction obtained with this instrument is comparable to that of astronomic observations.

176. Components

The artillery gyro azimuth surveying instrument consists of the following items (fig. 47):

a. Alinement Head. The alinement head contains a highly sensitive single axis rate gyroscope (fig. 48). Mounted to the gyroscope assembly is a mirror assembly used to check the collimation of the instrument. The mirror may be seen through the circular window installed in the side of the alinement head. A T2 theodolite (0.002 mil) is mounted on the top of the alinement head in such a manner that the horizontal circle of the theodolite is locked to the movement of the alinement head. This allows the azimuth of any line to be determined with reference to true north after orientation of the instrument has been completed. The base of the instrument contains the leveling and alinement assembly. The instrument is leveled in the same manner as a theodolite. The alinement controls consist of an azimuth lock (fast motion) and an azimuth vernier knob (slow motion) with an odometer-type scale. The complete alinement head weighs 61 pounds.

b. Electronic Package. The electronic package (fig. 47) converts the power from the power

source to a usable power to revolve the gyroscope in the alinement head. The control panel includes the controls and indicators necessary for the operation and to determine the directional alinement of the instrument. An integral voltmeter circuit is furnished to check various operations of the instrument and serves as an aid to troubleshooting. The electronic package contains six removable subassemblies called modules (fig. 49). This type of component packaging facilitates the replacement of faulty components. The complete electronic package weighs 52 pounds.

c. Power Source. The artillery gyro azimuth surveying instrument is primarily designed to operate from a power source of 24 volts direct current (DC). However, a powerpack contained in the bottom cover of the electronic package can be used to convert 110 volts alternating current (AC) to direct current.

d. Interconnection Cables. The instrument is provided with several cables. One cable is used to carry power from the electronic package to the alinement head. When the instrument is operated on direct current, either a 5 foot power cable (when the current is provided by separate batteries) or a 25 foot power cable (when the current is provided by batteries installed in a vehicle) is used to carry the power from the power source to the electronic package. When the instrument is operated on alternating current, two powerpack cables are used; one connects the power source to the powerpack and the other connects the powerpack to the electronic package.

e. Tripod. The tripod is a heavy duty, specially designed tripod with wooden legs or

shorter metal legs. The legs are interchangeable to allow operation of the instrument under

a wider scope of situations. The tripod with wooden legs weighs 21 pounds.

Section II. USE, CARE, AND MAINTENANCE OF ARTILLERY GYRO AZIMUTH SURVEYING INSTRUMENT

177. Setting up the Equipment

Setting up the equipment consists of removing components from containers, plumbing over the station to be occupied, assembling the components, leveling the instrument, attaching the necessary cables, and turning the alinement head so that the circular window is pointing approximately west.

178. Coarse Alinement

Coarse alinement includes the bias adjustment and the head alinement. *Bias adjustment*

consists of calibrating the instrument to insure that the only torque (force) exerted on the gyroscope will be the rotation of the earth. Calibration is accomplished by turning the selector switch to position 1 and the clamp switch to the READ position and then adjusting the calibrate knob until the indicator needle is zeroed. Bias torques that are compensated for by this adjustment are mechanical stresses, bearing friction, magnetic fields, fluid forces, etc. This step is performed before the gyroscope motor is turned on. *Head alinement*

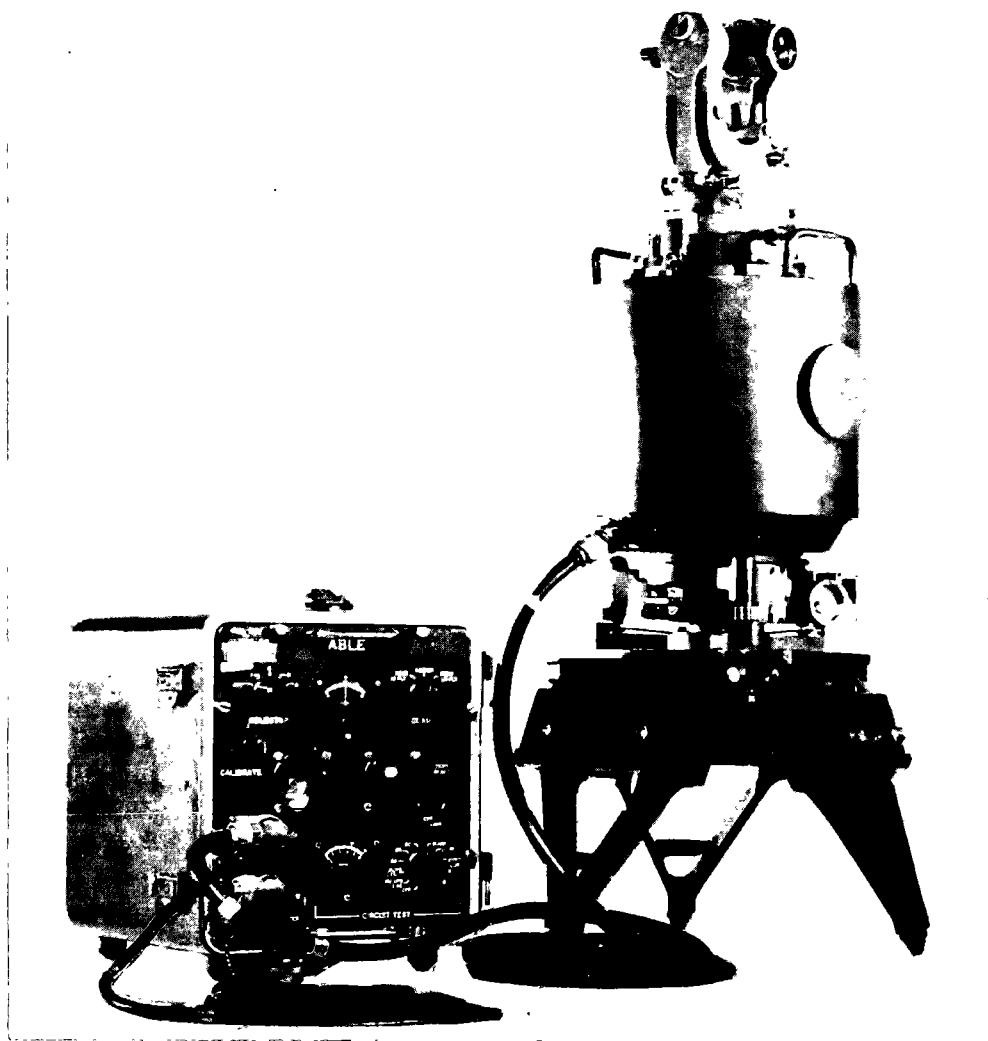


Figure 47. The artillery gyro azimuth surveying instrument.

consists of obtaining a coarse east-west direction with the instrument. This is accomplished by putting the gyroscope into motion and turning the alinement head until the indicator needle is nulled (zeroed). The gyroscope motor is turned on by turning the selector switch to position 2. The indicator needle is partially nulled in this phase of the operation by turning the alinement head manually until the indicator needle is less than three divisions away from zero. Care must be taken to insure that the alinement head is not moved unless the clamp switch is in the ADJUST position and that sufficient time is given for the indicator needle to settle down before reading the indi-

cator meter. The azimuth lock is then tightened, and the indicator needle is nulled within one graduation of zero by using only the azimuth vernier knob.

179. Fine Alinement

Fine alinement includes the final head alinement and the readout of direction. *The final head alinement* consists of obtaining a more sensitive reaction of the gyroscope to the rotation of the earth. This step is accomplished by turning the selector switch to position 3 and nulling the indicator needle by using only the azimuth vernier knob. The indicator needle is nulled within one graduation of zero. *Readout*

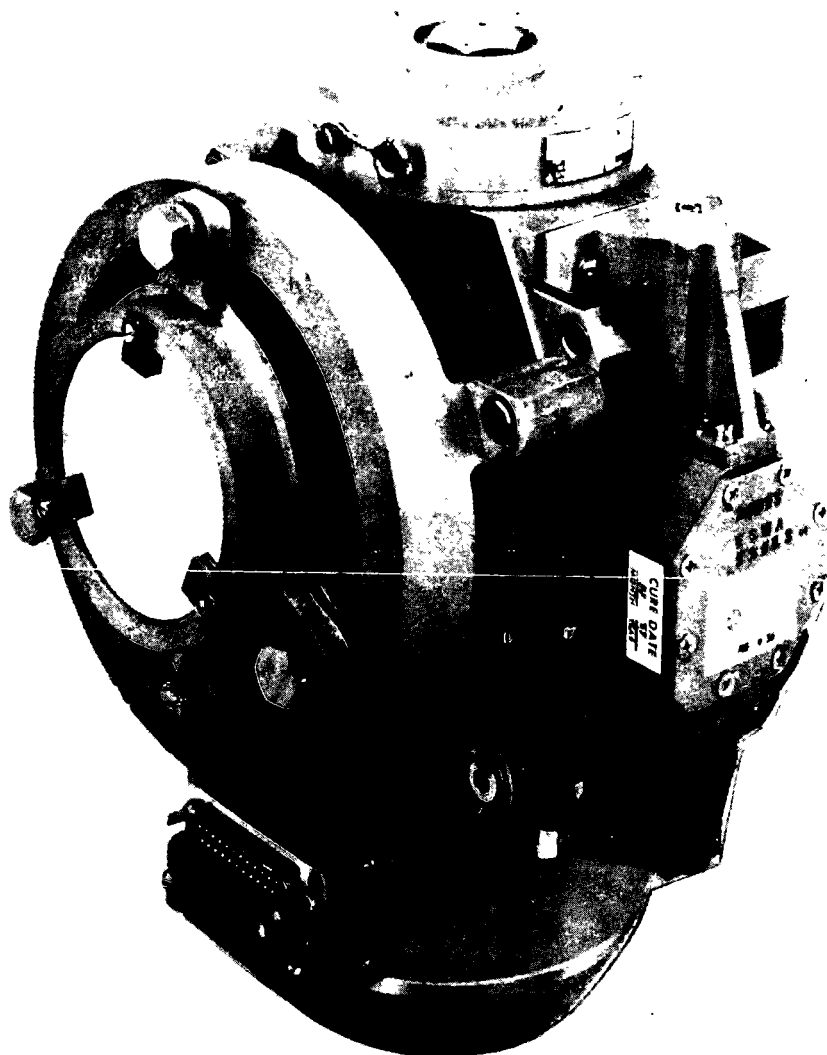


Figure 48. Single axis rate gyro.

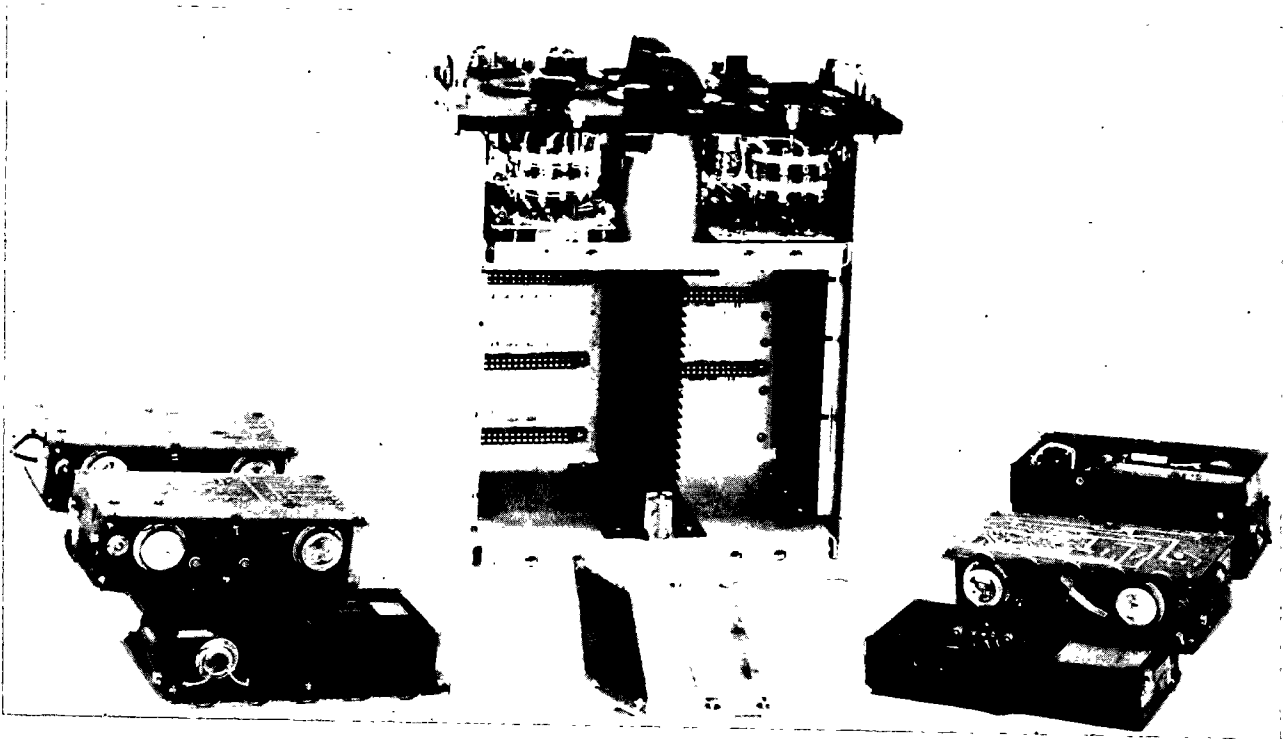


Figure 49. The electronic package disassembled.

of direction is accomplished by taking one position with the theodolite to a desired mark or reference point. These readings are then recorded and meaned. This gives a direction to the reference point with the gyroscope rotating in one direction. The selector switch is then turned to position 4. This causes the gyroscope to reverse its direction of rotation. Again the indicator needle is nulled within one graduation of zero by using only the azimuth vernier knob. By obtaining the relative position of the alinement head with the gyroscope rotating in a forward and a reverse motion, compensation is made for any further bias torques not compensated for by the calibration of the instrument. Readout of direction is again accomplished by taking one position with the theodolite and recording and meaning the new directions obtained. The directions obtained in positions 3 and 4 of the selector switch are meaned. This constitutes one set of readings.

This process is repeated until the required number of sets of readings are taken. The final step is to apply grid convergence to the mean true azimuth determined with the instrument. This will provide the grid azimuth from the instrument to the reference point.

180. Taking Down the Equipment

The equipment is taken down in the reverse order from which it was set up. Before removing the alinement head from the tripod, care must be taken to insure that the gyroscope is no longer revolving and that all switches are turned off. By placing the ear next to the alinement head, one can determine when the gyroscope has stopped by the cessation of the noise of rotation.

181. Care and Maintenance

Specific maintenance responsibilities and procedures are covered in appropriate technical bulletins and manuals.

CHAPTER 12

ALTIMETER

Section I. GENERAL

182. General

a. The surveying altimeter is used in artillery survey to determine height when stations do not have optical intervisibility. Though altimetry is not considered a precise method for determining heights, during normal weather conditions it is sufficiently accurate for artillery survey. The altimeter is used to determine the difference in height between two stations. This difference in height is then applied to the height of the known station to determine the height of the unknown station.

b. In altimetry, altitude (height) of points is determined from the difference in altimeter readings caused by changes in atmospheric pressure for different altitudes. The basic principle of altimetry is that the pressure caused by the weight of the column of air above the observer decreases as the observer rises in altitude. An assumption is made that points of equal pressure are of equal height. If weather conditions and instrument conditions were always standard and never varied, it would be possible to set up a pressure-altitude ratio that would enable an observer to measure the pressure at any given point and then rapidly compute the altitude (height) of that point. In altimetry this is essentially what takes place; however, because weather conditions, instruments, and geological and geographical conditions vary widely and in certain areas air is compressed and in other areas air is rarefied, it is not possible to set up a pressure-altitude ratio which by itself will always produce an accurate result. It is therefore necessary to establish a set of standard conditions and use this as a basis for the pressure-altitude ratio.

Variations from this standard set of conditions would be converted to corrections and applied as required to compensate for their effect. The standard conditions for altimetry as it is used by the artillery are as follows:

- (1) Instrument temperature—75° F.
- (2) Air temperature—50° F.
- (3) Relative humidity—100 percent.
- (4) Latitude—45° N(S).
- (5) Altitude—(+) 45 meters (m).
- (6) Gravity acceleration—32.2 feet per second per second (ft/sec/sec).
- (7) Wind—0 miles per hour (mph).

183. Surveying Altimeter

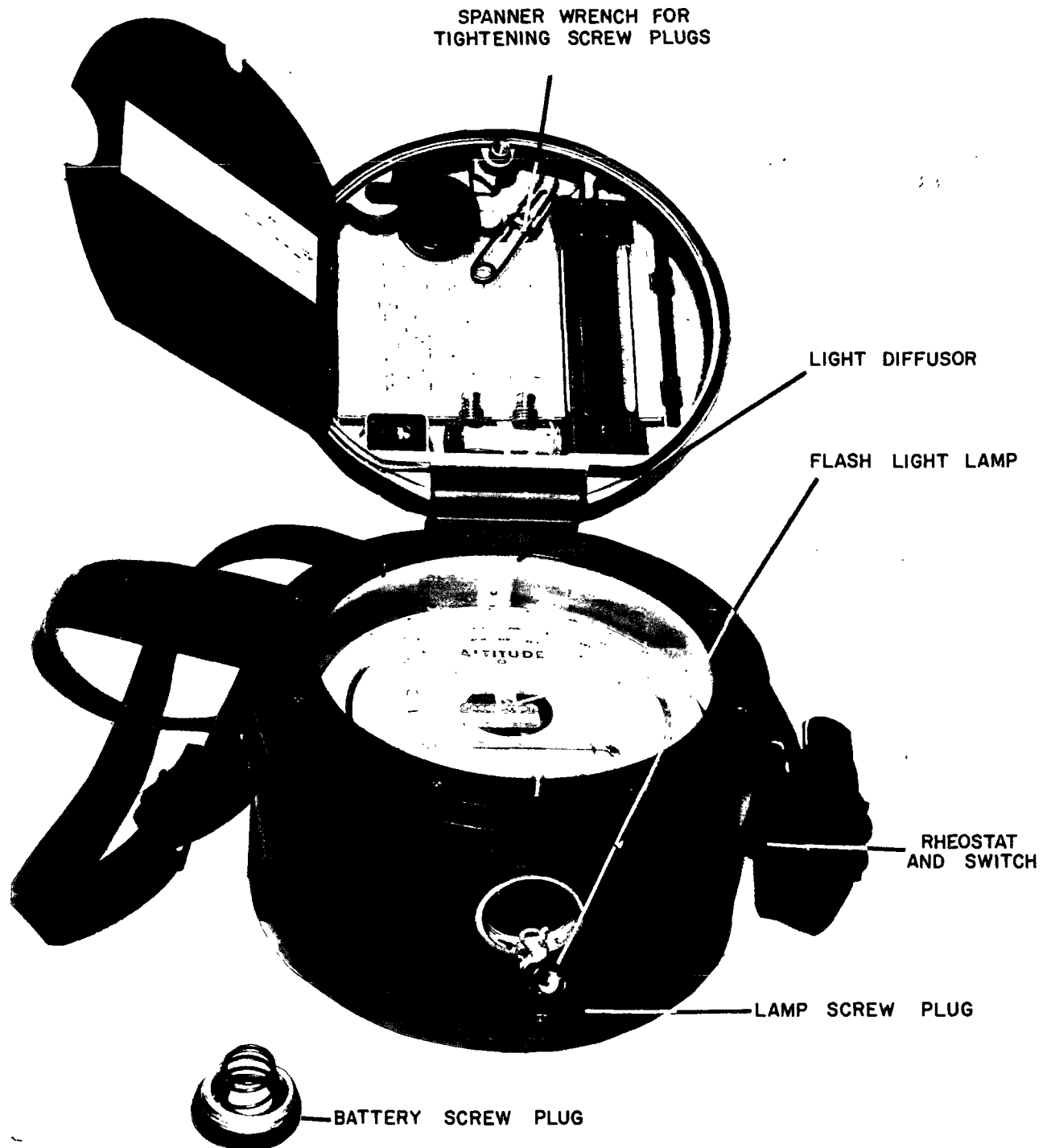
a. The surveying altimeter is an aneroid barometer which measures atmospheric pressure by mechanical means. The scales are so graduated that air pressure is indicated in units of height (meters).

b. The surveying altimeter issued to artillery units (fig. 50) has a range under standard conditions of 300 meters below to 4,500 meters above mean sea level. The instrument contains an aneroid element consisting of a single vacuum chamber. Expansion and contraction of this chamber are indicated by rotation of an indicating hand and movement of a revolution indicator.

c. The altimeter has a circular dial with four scales, two outer and two inner, with an annular mirror located between the outer and inner scales (fig. 51). The indicating hand makes nearly four revolutions in measuring throughout the range of the altimeter. A revolution indicator indicates the scale which should be read. Zero on the dial corresponds to

a pressure-height of 300 meters below mean sea level under standard conditions; 4800 on the dial corresponds to 4,500 meters above mean sea level under standard conditions. The least reading on the scales is 2 meters. Each altimeter dial is custom calibrated for the vacuum chamber and mechanical linkage with

which it is to be used. For this reason, the dial, the vacuum chamber, all parts of the mechanical linkage, and the instrument temperature correction chart are not interchangeable with corresponding parts of other altimeters. In the face of the dial is a desiccant-condition indicator which becomes



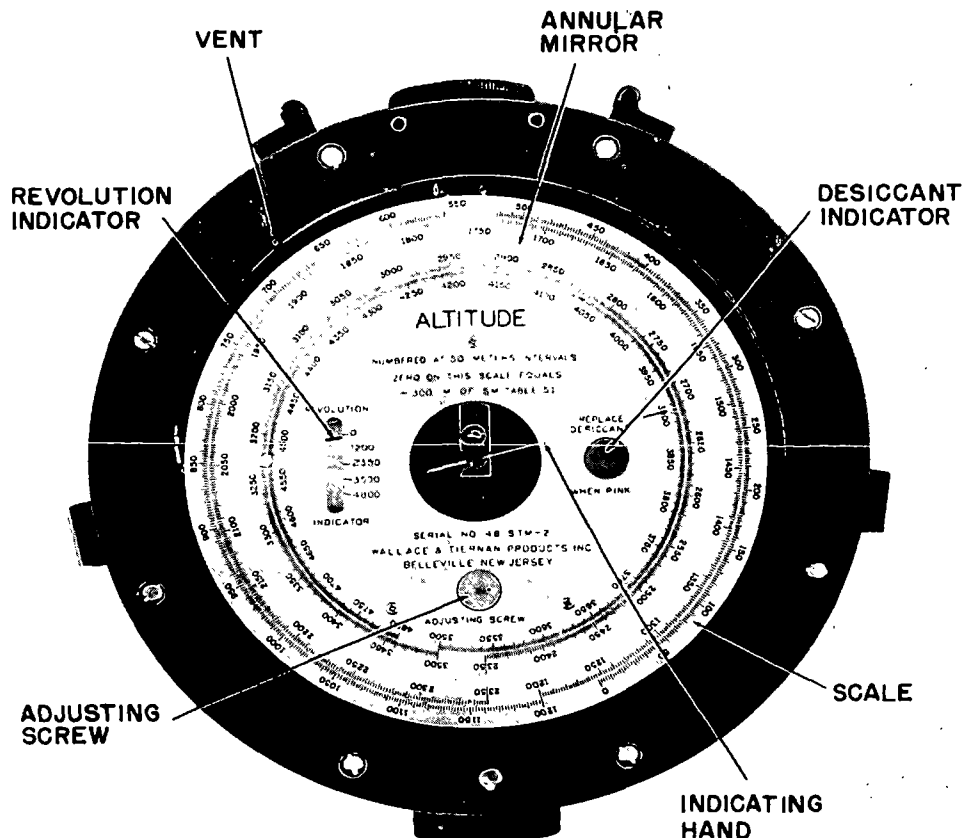
pink when moisture within the case is excessive.

d. The case is airtight except for a small vent which permits the pressure inside the case to become equal to that outside. The case can be made completely airtight by shifting a movable vent cap to the closed position and closing the lid. The vent normally is left open. However, it should be closed when the instrument is packed for shipping. A built-in night-lighting system utilizes standard flashlight batteries and lamps. Scale lighting is adjusted by a switch and rheostat assembly. Batteries should be placed in the case only for actual night operations. A silica gel desiccant is in a container in the lower part of the case. Carried in the lid of the case are a reading glass, a folding sling psychrometer, a spanner wrench, calibration charts, correction tables, and spare parts.

184. Sling Psychrometer

a. A folding sling psychrometer is carried in the lid of the altimeter. The psychrometer consists of two identical Fahrenheit thermometers mounted side by side with a cloth wick on one of them (wet bulb). Psychrometer readings are made to the nearest degree Fahrenheit, as follows: The psychrometer is unfolded, the cloth wick is saturated with clean water, and the psychrometer is revolved at a rate of 2 revolutions per second for at least 1 minute. Temperatures are immediately read and recorded, first the "wet bulb" and then the "dry bulb."

b. The thermometers should be checked against a standard thermometer or against each other. When this check is made the "wet bulb" readings must be made with the wick dry. A correction factor should be determined



Section II. USE OF THE ALTIMETER

Figure 51. Altimeter dial.

for any thermometer that does not agree within 2° of the standard or other thermometers.

185. Weather Conditions

The accuracy of heights determined by altimetric leveling depends on the stability of prevailing weather conditions. Valid results cannot be obtained during periods of strong or gusty winds or during thunderstorms or other violent weather. The best results are obtained in winds of 10 miles per hour or less. Generally, the hours from 1000 to 1400 are the most unstable parts of the day and should be avoided if possible for making altimeter readings. The atmospheric conditions that prevail during fog, mist, or light rain are usually suitable for altimetric leveling. The altimeter should be shaded from the direct rays of the sun when readings are being taken.

186. Care and Maintenance

a. The surveying altimeter is a delicate instrument although rugged enough to be used for field survey if handled with care and protected from shock. The instrument and its accessories should be kept clean and dry. The window of the instrument is made of clear plastic, which scratches easily. It should be brushed with a camel's-hair brush to remove dust and polished with lens tissue or a soft rag. The window should be waxed. The instrument should *not be oiled*. Oil will interfere with the operation of the instrument and cause erroneous readings.

b. Artillery personnel are not authorized to repair the instrument. They should never remove the window. The spare hand which is

issued with the instrument should be replaced by engineer instrument repair personnel if replacement is necessary.

c. Artillery survey personnel are authorized to remove and dry or replace the silica gel desiccant in the instrument when the desiccant-condition indicator turns pink. The silica gel can be dried by heating it to 300° F. for at least 10 minutes.

d. Artillery survey personnel are authorized to replace the lamp for the night-lighting system when it is necessary and to insert and remove the batteries for the night-lighting system. The batteries should not be inserted until the instrument is to be used at night. After its use at night, the batteries should be removed.

e. Artillery survey personnel are authorized to replace a broken thermometer in the sling psychrometer. A thermometer can be replaced by removing the screw cap from the end of the psychrometer head. The cork disc for the cap must be in place when the cap is replaced.

f. Altimeters to be used during fieldwork should be set so that the scale readings of all instruments when located at the same station will read nearly the same, preferably within 10 meters. This will simplify construction of the comparison adjustment graph (figs. 53 and 62). The adjustment of instrument scales should be performed by engineer instrument repair personnel. The amount of the difference in scale reading when two altimeters are read simultaneously at the same station has no effect on the accuracy of the scale readings.

Section II. USE OF THE ALTIMETER

187. Methods of Altimetry

a. Two methods of altimetry are employed in artillery survey. These methods are—

- (1) The single-base method (par. 194).
- (2) The leapfrog method (par. 195).

b. A base station (point of known height) and a field station(s) (point(s) for which height is desired) are used in both methods.

c. Both methods of altimetry require that simultaneous readings of altimeter scales be taken at the base station and at the field sta-

tion(s). These simultaneous scale readings, adjusted for instrumental differences, are compared to determine the indicated difference in height between the base station and the field station(s). The wet and dry bulb (fig. 54) correction is applied to the difference in adjusted scale readings to obtain the relative height(s).

d. The field station and base station make simultaneous observations after coordinating the time by radio communication. When a radio is not available simultaneous observations

may be made by a prearranged observing schedule. The watch of the field station observer must be synchronized with the watch of the base station observer.

e. During normal weather conditions, a majority of the heights obtained by altimetry will be correct within 3 meters and the maximum error will seldom exceed 5 meters, provided the following precautions are taken:

- (1) Individual instrument temperature correction is applied.
- (2) Comparison adjustment is made.
- (3) Wet and dry bulb correction is made (fig. 54).
- (4) Difference in height between base station and field station is less than 200 meters.
- (5) Distance between base station and field station is less than 20,000 meters.

f. The *artillery surveyor* need not make corrections for tables II and III which are contained in the lid of the altimeter.

188. Reading the Scales

The altimeter scales are read as follows:

a. Place the instrument as nearly level as possible with the dial in the horizontal position. The instrument must be protected from the sun and the wind.

b. Tap the window of the instrument lightly to overcome any lag due to static electricity.

c. Position the eye so that the indicating hand and its reflection in the annular mirror coincide. *Care must be taken to select the reflection of the hand and not its shadow.*

d. Determine the scale which should be read by the revolution indicator.

e. Read the proper scale under the indicating hand to the nearest 0.5 meter. The reading glass may be used to aid in reading the scale.

Note. Extreme care must be taken to insure that the correct scale is read since the scales increase in value in a counter-clockwise direction.

189. Corrections and Adjustments

a. The scale reading of each instrument should be corrected for the individual instrument temperature correction (par. 190). The application of this correction provides the *corrected* scale reading.

b. The comparison adjustment should be applied to the corrected scale reading of the field station instrument (par. 191). The application of this adjustment provides the *adjusted* scale reading.

c. The difference between the *corrected* scale reading of the base station and the *adjusted* scale reading of the field station should be corrected for air temperature and relative humidity (par. 192).

190. Individual Instrument Temperature Correction

a. Each artillery surveying altimeter is calibrated at an air temperature of 75° F. If the instrument temperature differs from 75° F., it will change the value of the scale reading. When maximum accuracy is required, a correction must be made for this difference.

b. The corrections for temperature difference are determined from the individual temperature correction chart which is fastened in the lid of each instrument. This chart is different for each instrument. Figure 52 is an example of the temperature correction chart for one instrument. To obtain the correction which should be applied to an instrument reading—

- (1) Locate the position along the bottom of the graph which corresponds to the scale reading, taken to the nearest 100 meters.
- (2) Project this point upward along a line parallel to the vertical lines of the graph to the curved line of the graph.
- (3) From the point of intersection of the projected line and the curved line, project a second line to the left parallel to the horizontal lines on the graph.
- (4) At the intersection of the second projected line with the left side of the graph, determine the meters correction per degree Fahrenheit, noting the sign of the correction.
- (5) Multiply this factor by the number of degrees by which the instrument temperature at which the scale reading was taken differs from 75° F. (The sign of the product is the sign of the correction.)

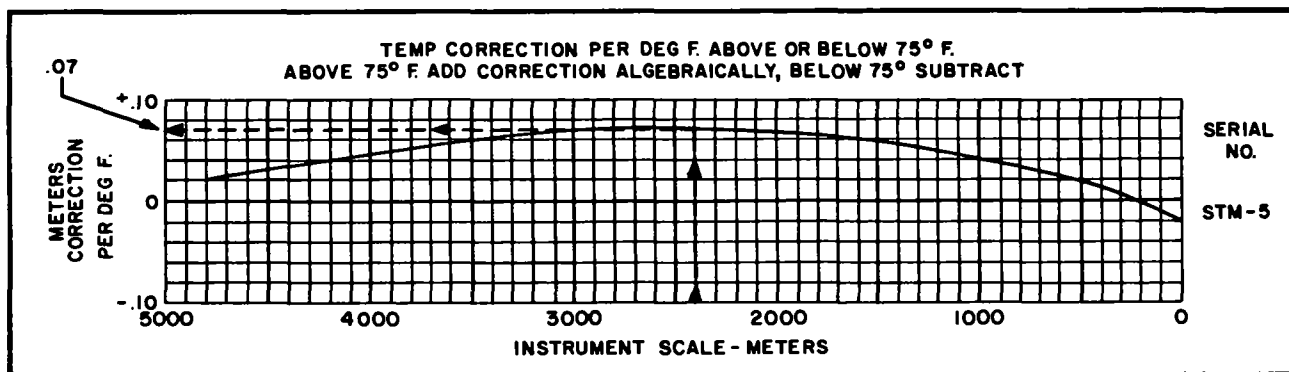


Figure 52. Individual instrument temperature correction chart.

(6) Apply this value to the altimeter scale reading. If the air temperature was above 75° F, add the value algebraically. If the air temperature was below 75° F., subtract the value algebraically. This correction provides the *corrected scale reading*.

c. The following is an example of the application of an individual instrument temperature correction—

- (1) 2431.5 (scale reading).
- (2) 50° F (instrument temperature).
- (3) $75^\circ - 50^\circ = 25^\circ$ (number of degrees to which correction is applied).
- (4) +0.07 meter (correction per degree) (fig. 52).
- (5) $25^\circ \times 0.07 = 1.75$ meters (correction).
- (6) $2431.5 - (+1.8) = 2429.7$ (corrected scale reading).

191. Comparison Adjustment

a. The base station instrument is placed on a station of known height. The field station instrument is placed beside and at the same height as the base station instrument. The initial comparison is made by recording the time and the scale reading of each instrument. The base station scale reading is recorded in the base station field book (fig. 55). For comparison purposes, both the base and field corrected scale readings are recorded in the field station record book (figs. 53 and 62). The base station instrument remains in the same position throughout the altimeter survey. The field station instrument is taken to stations of unknown height.

b. After the field survey is completed, the final comparison is made at the same station and in the same manner as the initial comparison (figs. 53 and 62).

c. The time lapse between the initial and final comparison should be held to a minimum, less than 4 hours if possible.

d. A comparison adjustment graph is constructed in the field station record book by inserting values on the lines in the record book (fig. 53). The procedures in preparing the graph are as follows:

- (1) Use initial watch time and difference in corrected scale reading to plot the initial comparison point on graph.
- (2) Use final watch time and difference in corrected scale reading to plot the final comparison point on graph.
- (3) Join points with a straight line.
- (4) Using watch time for each reading in the field record book as argument, read comparison adjustment from left side of graph.

192. Correction for Air Temperature and Relative Humidity

a. A folding sling psychrometer is carried in the lid of the altimeter case. The psychrometer consists of two thermometers; the wick of one thermometer is saturated with water to give the *wet bulb* temperature, and the other is left dry to give the *dry bulb* temperature. These two factors are used to obtain the correction to the difference in height for air temperature and relative humidity.

b. To measure these two correction factors—

- (1) Remove psychrometer from case.

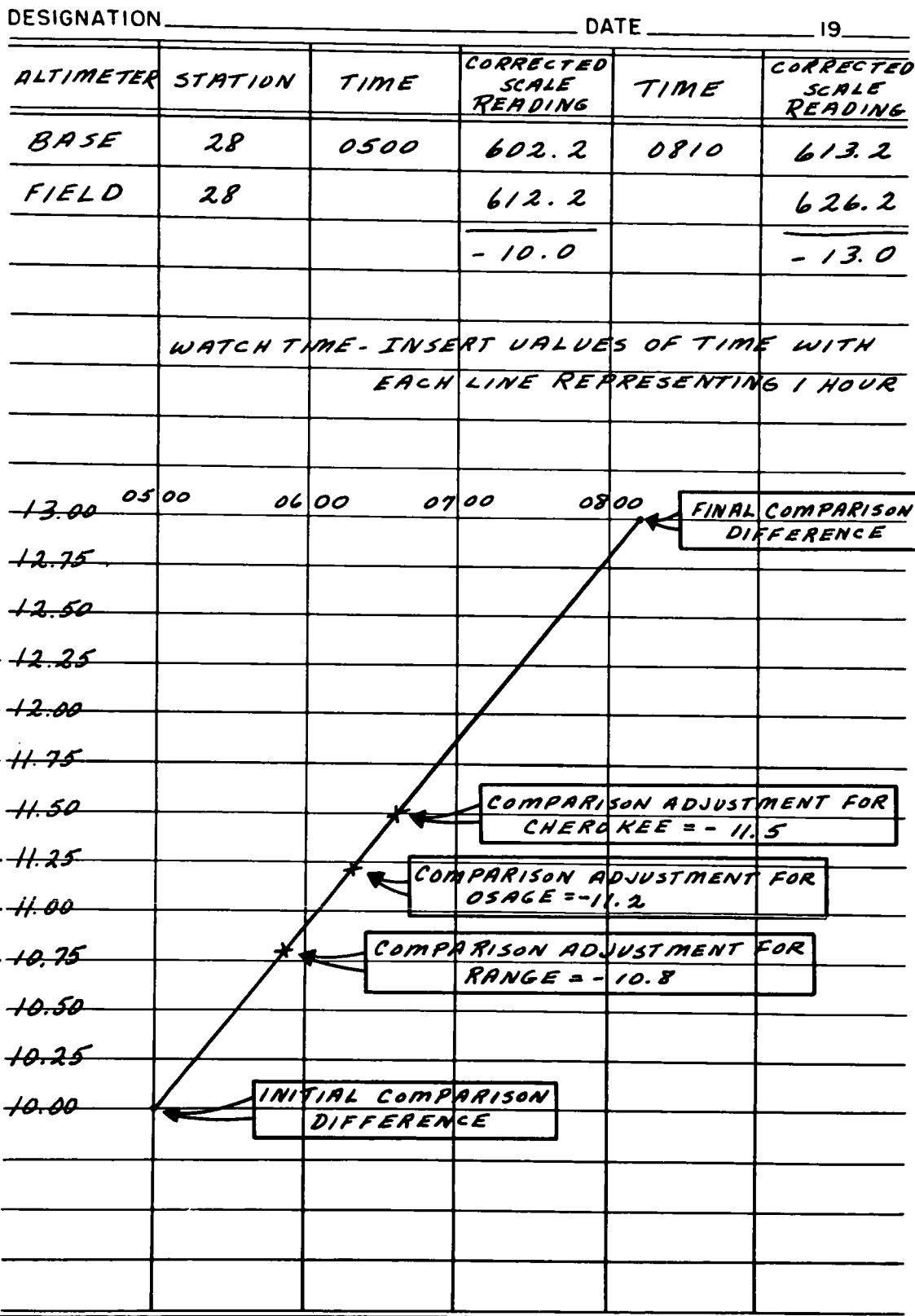


Figure 53. Comparison adjustment graph (single-base).

- (2) Slide handle off as far as it will go.
- (3) Rotate the thermometer 180° and the handle 90° on its link.
- (4) Saturate the wick of the wet bulb thermometer with clean water.
- (5) Revolve thermometers two or more times a second for at least 1 minute.
- (6) Immediately read and record the wet bulb and then the dry bulb temperatures.

(7) Repeat (5) and (6) above until two successive readings agree within 1°. Record the lowest reading on both the wet and dry bulb thermometers.

c. By knowing the wet and dry bulb temperatures, the correction factor can be determined from the chart in figure 54. The chart is entered with the wet bulb temperature at the top and the dry bulb temperature on the left hand side, and the intersection of the two columns is the correction to be multiplied by the differ-

TABLE I

AIR TEMPERATURE & RELATIVE HUMIDITY CORRECTION FACTOR FOR ALTITUDE

Temperature Below Freezing		Wet Bulb Temperature Degrees F.																	
Deg. F.	Factor	32	34	35	38	40	42	44	46	48	50	52	54	56	58	60	62	64	66
-55	0.772	32	0.967																32
-60	0.782	34	0.971	0.971															34
-55	0.792	38	0.978	0.978	0.979	0.979													36
-50	0.802	40	0.982	0.982	0.983	0.983	0.984												38
-45	0.812	42	0.985	0.986	0.986	0.987	0.987	0.988											40
-40	0.822	44	0.989	0.989	0.990	0.990	0.991	0.991	0.992										42
-38	0.826	46	0.992	0.993	0.993	0.994	0.995	0.995	0.996	0.996									44
-36	0.830	48	0.996	0.997	0.997	0.998	0.998	0.999	0.999	1.000	1.000								46
-34	0.834	50	1.000	1.000	1.001	1.001	1.002	1.002	1.003	1.003	1.004	1.005							48
-32	0.838	52	1.003	1.004	1.004	1.005	1.005	1.006	1.006	1.007	1.008	1.008	1.009						50
-30	0.842	54	1.007	1.008	1.008	1.008	1.009	1.010	1.010	1.011	1.011	1.012	1.012	1.013					52
-28	0.846	56	1.011	1.011	1.012	1.012	1.013	1.013	1.014	1.014	1.015	1.016	1.016	1.017	1.017				54
-26	0.850	58	1.014	1.015	1.015	1.016	1.017	1.017	1.018	1.018	1.019	1.019	1.020	1.020	1.021	1.022			56
-24	0.854	60	1.018	1.019	1.019	1.020	1.020	1.021	1.021	1.022	1.022	1.023	1.024	1.024	1.025	1.026	1.026		58
-22	0.858	62	1.022	1.022	1.023	1.023	1.024	1.024	1.025	1.025	1.026	1.027	1.027	1.028	1.028	1.029	1.030	1.031	60
-20	0.862	64	1.026	1.026	1.027	1.027	1.028	1.028	1.029	1.029	1.030	1.031	1.031	1.032	1.032	1.033	1.034	1.035	62
-18	0.866	66	1.030	1.030	1.031	1.031	1.032	1.032	1.033	1.033	1.034	1.034	1.035	1.035	1.036	1.037	1.038	1.039	64
-16	0.870	68	1.033	1.034	1.034	1.035	1.035	1.036	1.036	1.037	1.038	1.038	1.039	1.040	1.040	1.041	1.042	1.043	66
-14	0.874	70	1.037	1.038	1.038	1.039	1.039	1.040	1.041	1.041	1.042	1.043	1.043	1.044	1.045	1.046	1.046	1.047	68
-12	0.878	72	1.041	1.042	1.042	1.043	1.043	1.044	1.045	1.045	1.046	1.047	1.047	1.048	1.049	1.050	1.051	1.051	70
-10	0.882	74	1.045	1.046	1.046	1.047	1.047	1.048	1.049	1.049	1.050	1.051	1.051	1.052	1.053	1.054	1.054	1.055	72
-8	0.886	76	1.049	1.049	1.050	1.050	1.051	1.051	1.052	1.052	1.053	1.054	1.054	1.055	1.056	1.057	1.057	1.058	74
-6	0.890	78	1.053	1.054	1.054	1.055	1.055	1.056	1.056	1.057	1.057	1.058	1.058	1.059	1.060	1.061	1.061	1.062	76
-4	0.894	80	1.057	1.057	1.058	1.058	1.059	1.060	1.060	1.061	1.061	1.062	1.062	1.063	1.064	1.065	1.065	1.066	78
-2	0.898	82	1.061	1.061	1.062	1.062	1.063	1.063	1.064	1.065	1.065	1.066	1.066	1.067	1.067	1.068	1.068	1.069	80
0	0.902	84	1.065	1.065	1.066	1.066	1.067	1.067	1.068	1.068	1.069	1.070	1.070	1.071	1.071	1.072	1.072	1.073	82
2	0.906	86	1.069	1.069	1.070	1.070	1.071	1.071	1.072	1.072	1.073	1.073	1.074	1.074	1.075	1.075	1.076	1.076	84
4	0.910	88	1.072	1.072	1.073	1.073	1.074	1.074	1.075	1.075	1.076	1.076	1.077	1.077	1.078	1.078	1.079	1.079	86
6	0.914	90	1.076	1.077	1.078	1.078	1.079	1.079	1.080	1.080	1.081	1.081	1.082	1.082	1.083	1.083	1.084	1.084	88
8	0.919	92	1.080	1.081	1.081	1.082	1.083	1.083	1.084	1.084	1.085	1.085	1.086	1.086	1.087	1.087	1.088	1.088	90
10	0.923	94	1.084	1.085	1.086	1.087	1.087	1.088	1.089	1.089	1.090	1.090	1.091	1.091	1.092	1.092	1.093	1.093	92
12	0.927	96	1.088	1.089	1.090	1.090	1.091	1.092	1.092	1.093	1.093	1.094	1.094	1.095	1.095	1.096	1.096	1.097	94
14	0.931	98	1.093	1.093	1.094	1.095	1.095	1.096	1.096	1.097	1.097	1.098	1.098	1.099	1.099	1.100	1.100	1.101	96
16	0.935	100	1.096	1.097	1.097	1.098	1.099	1.099	1.100	1.100	1.101	1.101	1.102	1.102	1.103	1.103	1.104	1.104	98
18	0.939	102	1.100	1.101	1.102	1.102	1.103	1.103	1.104	1.104	1.105	1.105	1.106	1.106	1.107	1.107	1.108	1.108	100
20	0.943	104	1.104	1.105	1.105	1.106	1.106	1.107	1.107	1.108	1.108	1.109	1.109	1.110	1.110	1.111	1.111	1.112	102
22	0.947	106	1.108	1.109	1.109	1.110	1.110	1.111	1.111	1.112	1.112	1.113	1.113	1.114	1.114	1.115	1.115	1.116	104
24	0.951	108	1.112	1.113	1.113	1.114	1.114	1.115	1.115	1.116	1.116	1.117	1.117	1.118	1.118	1.119	1.119	1.120	106
26	0.955	110	1.116	1.117	1.117	1.118	1.118	1.119	1.119	1.120	1.120	1.121	1.121	1.122	1.122	1.123	1.123	1.124	108
28	0.959	112	1.120	1.121	1.121	1.122	1.122	1.123	1.123	1.124	1.124	1.125	1.125	1.126	1.126	1.127	1.127	1.128	110
30	0.963	114	1.124	1.125	1.125	1.126	1.126	1.127	1.127	1.128	1.128	1.129	1.129	1.130	1.130	1.131	1.131	1.132	112
																			114

This chart is to be used to obtain the temperature and relative humidity corrections required when using the single-beam method of altimeter leveling. Use only with altimeters set and calibrated in meters according to the Smithsonian Meteorological Table No. 51.

EXAMPLE OF USE OF CHART

Assume altimeter "A" reads 900 meters and "B" reads 1100 meters, dry bulb 80°F, wet bulb 60°F. Find 80 in dry bulb temperature column, follow across to 60 of wet bulb temperature column. Read correction factor 1.063. Corrected altitude difference = (1100-900) (1.063) = 212.6 meters. Interpolate the correction factor to the nearest .001

(continued on facing page)

Figure 54. Temperature and humidity correction chart.

TABLE I (continued)

AIR TEMPERATURE & RELATIVE HUMIDITY CORRECTION FACTOR FOR ALTITUDE

	Wet Bulb Temperature Degrees F.																98	100	102	104	106	108	110
	68	70	72	74	76	78	80	82	84	86	88	90	92	94	96								
68	1.044																						68
70	1.048	1.049																					70
72	1.052	1.052	1.053																				72
74	1.055	1.056	1.057	1.058																			74
76	1.059	1.060	1.061	1.062	1.063																		76
78	1.063	1.063	1.064	1.065	1.066	1.067																	78
80	1.066	1.067	1.068	1.069	1.070	1.071	1.072																80
82	1.070	1.071	1.072	1.073	1.074	1.075	1.076	1.077															82
84	1.074	1.074	1.075	1.076	1.077	1.078	1.080	1.081	1.082														84
86	1.077	1.078	1.079	1.080	1.081	1.082	1.083	1.084	1.086	1.087													86
88	1.081	1.082	1.083	1.084	1.085	1.086	1.087	1.088	1.089	1.091	1.092												88
90	1.085	1.085	1.086	1.087	1.088	1.090	1.091	1.092	1.093	1.094	1.096	1.097											90
92	1.088	1.089	1.090	1.091	1.092	1.093	1.094	1.096	1.097	1.098	1.099	1.101	1.102										92
94	1.092	1.093	1.094	1.095	1.096	1.097	1.098	1.099	1.100	1.102	1.103	1.104	1.106	1.107									94
96	1.096	1.096	1.097	1.098	1.099	1.101	1.102	1.103	1.104	1.105	1.107	1.108	1.109	1.111	1.112								96
98	1.100	1.100	1.101	1.102	1.103	1.104	1.105	1.107	1.108	1.109	1.110	1.112	1.113	1.115	1.116	1.118							98
100	1.103	1.104	1.105	1.106	1.107	1.108	1.109	1.110	1.111	1.113	1.114	1.115	1.117	1.118	1.120	1.122	1.123						100
102	1.106	1.107	1.108	1.109	1.110	1.112	1.113	1.114	1.115	1.116	1.118	1.119	1.120	1.122	1.124	1.125	1.127	1.128					102
104	1.110	1.111	1.112	1.113	1.114	1.115	1.116	1.118	1.119	1.120	1.121	1.123	1.124	1.126	1.127	1.129	1.130	1.132	1.134				104
106	1.114	1.115	1.116	1.117	1.118	1.119	1.120	1.121	1.122	1.124	1.125	1.126	1.128	1.129	1.131	1.132	1.134	1.136	1.137	1.139			106
108	1.118	1.118	1.119	1.120	1.121	1.123	1.124	1.125	1.126	1.127	1.129	1.130	1.131	1.133	1.135	1.136	1.138	1.139	1.141	1.143	1.144		108
110	1.121	1.122	1.123	1.124	1.125	1.127	1.128	1.130	1.131	1.132	1.134	1.135	1.137	1.138	1.140	1.142	1.143	1.145	1.146	1.148	1.150	110	
112	1.125	1.126	1.127	1.128	1.129	1.130	1.131	1.132	1.133	1.135	1.136	1.137	1.139	1.140	1.142	1.144	1.145	1.147	1.148	1.150	1.152	1.153	112
114	1.129	1.129	1.130	1.131	1.132	1.133	1.135	1.136	1.137	1.138	1.140	1.141	1.142	1.144	1.145	1.147	1.149	1.151	1.152	1.154	1.156	1.157	114
116	1.132	1.133	1.134	1.135	1.136	1.137	1.138	1.139	1.141	1.142	1.143	1.145	1.146	1.148	1.149	1.151	1.153	1.154	1.156	1.158	1.159	1.161	116
118	1.136	1.137	1.138	1.139	1.140	1.141	1.142	1.143	1.144	1.146	1.147	1.148	1.150	1.151	1.153	1.154	1.156	1.158	1.160	1.161	1.163	1.165	118
120	1.139	1.140	1.141	1.142	1.143	1.144	1.146	1.147	1.148	1.149	1.151	1.152	1.153	1.155	1.156	1.158	1.160	1.162	1.164	1.165	1.167	1.169	120
122	1.143	1.144	1.145	1.146	1.147	1.148	1.149	1.150	1.151	1.152	1.154	1.156	1.157	1.159	1.160	1.162	1.164	1.166	1.167	1.169	1.171	1.173	122
124	1.147	1.148	1.149	1.150	1.151	1.152	1.153	1.154	1.155	1.157	1.158	1.159	1.161	1.162	1.164	1.166	1.167	1.169	1.171	1.172	1.174	1.176	124
126	1.150	1.151	1.152	1.153	1.154	1.155	1.157	1.158	1.159	1.160	1.162	1.163	1.164	1.166	1.168	1.169	1.171	1.173	1.174	1.176	1.178	1.180	126
68	70	72	74	76	78	80	82	84	86	88	90	92	94	96	98	100	102	104	106	108	110		

Figure 54—Continued.

ence in the corrected scale reading of the base altimeter and the adjusted scale reading of the field altimeter. This correction should be interpolated to the thousandth in table I (fig. 54).

193. Precautions and Limitations to be Observed when Establishing Height with Altimeters

a. The base and field altimeters should be observed under similar conditions in the field and protected from the sun and strong wind. The altimeter should be shaded when it is being moved between stations.

b. The altimeter must be in a horizontal position when observed, preferably on a level and stable surface.

c. The altimeter should be cushioned against road shock, and sudden jarring should be avoided at all times.

d. Observations should be avoided during midday.

e. Observations should be avoided during thunderstorms, whirlwinds, gusty winds, or squalls.

f. Comparison readings should not be taken over 4 hours apart.

g. Base and field station watches must be synchronized.

h. The difference in height between base and field station(s) should be less than 200 meters.

i. The field station(s) should be less than 20,000 meters from the base station.

Section III. PROCEDURES AND COMPUTATIONS

194. Single-Base Method

a. The single-base method of altimetry requires one station of known or assumed height (base station). If possible, the base station should be centrally located with respect to the points for which the heights are desired (field stations). In order to obtain the required accuracy, the field station(s) must be within 20,000 meters horizontally and 200 meters vertically of the base station. The accuracy of the height determination will increase as the horizontal and vertical distance between the base and field station(s) decreases.

b. Techniques of observing are the same as those discussed in paragraph 188.

c. Recordings are made in DA Form 5-72 (Level, Transit and General Survey Record Book). The base station recorder's notes are shown in figure 55. The field station recorder's notes are shown in figure 56. The base station will record both wet and dry bulb temperatures. The field station will determine comparison adjustment and adjusted scale reading (par. 191). Both the base and field stations record the following—

- (1) Station at which observation(s) is made.
- (2) Time of observation.
- (3) Instrument temperature.
- (4) Scale reading.
- (5) Instrument temperature correction (par. 190).
- (6) Corrected scale reading (par. 190).

d. Computations for the single-base method are performed on DA Form 6-27 (Computation—Altimetric Height) (fig. 57). Instructions for the use of the form are contained on the reverse side of the form (fig. 58). Figure 58 contains a note as to the probable results because of the deletion of certain correction factors which may be applied on the form. Also contained on the reverse side of the form is a height conversion section which is self-explanatory. Figure 57 is an example of computations for the single-base problem shown in figures 53, 55, and 56.

195. Leapfrog Method

a. In the leapfrog method (fig. 59), two altimeters (A and B) are read simultaneously at a

BASE STATION: TOP

DESIGNATION ALTIMETRY SINGLE-BASE DATE 20 JULY 19 60

BASE STATION	TIME	INST TEMP	SCALE READING	INST TEMP CORRECTION	CORRECTED SCALE READING
TOP	0500	96	603.0	-.8	602.2
	0550	100	603.5	-1.0	602.5
	0615	98	606.0	-.9	605.1
	0630	96	606.5	-.8	605.7
	0810	94	614.0	-.8	613.2
1	2	3	4	5	6

- Column 1 Base station
 2 Time of observation
 3 Instrument temperature
 4 Base station altimeter scale reading
 5 Instrument temperature correction (par 190)

WEATHER: CLEAR-WARM CH OF PARTY: NELSON

INSTRUMENT NR: 7716 OBSERVER: SCHOEFF

TEMPERATURE		REMARKS		
DRY	WET			
		NO WIND		
88	76			
89	77			
90	77			
7	8			

- Column 6 Corrected scale reading, algebraic sum, column 4 and 5 (par 190)
 7 Base station wet bulb temperature (par 192, a & b)
 8 Base station dry bulb temperature (par 192, a & b)

Figure 55. Base station recorder's notes for altimetry (single-base).

FIELD STATION: RANGE-OSAGE-CHEROKEE					
DESIGNATION <i>ALTIMETRY SINGLE-BASE</i> DATE <i>20 JULY</i> 19 <i>60</i>					
FIELD STATION	TIME	INST TEMP	SCALE READING	INST TEMP CORRECTION	CORRECTED SCALE READING
TOP	0500	97	612.0	+ .2	612.2
RANGE	0550	92	732.5	+ .2	732.7
OSAGE	0615	96	722.0	+ .2	722.2
CHEROKEE	0630	98	701.5	+ .2	701.7
TOP	0810	91	626.0	+ .2	626.2
1	2	3	4	5	6

- Column 1 Field station (for comparison adjustment the first and last observations are always made at the base station)
 2 Time of observation
 3 Instrument temperature
 4 Field station altimeter scale reading

WEATHER: <i>CLEAR-WARM</i>		CH OF PARTY: <i>NELSON</i>	
INSTRUMENT NR: <i>7717</i>		OBSERVER: <i>BOWDEN</i>	
COMPARISON ADJUSTMENT	ADJUSTED SCALE READING	REMARKS	
- 10.8	721.9	NO WIND	
- 11.2	711.0		
- 11.5	690.5		
7	8		

- Column 5 Instrument temperature correction (par 190)
 6 Corrected scale reading, algebraic sum, column 4 and 5 (par 190)
 7 Comparison adjustment (par 191)
 8 Adjusted scale reading column 6 plus 7 (par 191)

Figure 56. Field station recorder's notes for altimetry (single-base).

base (known) station (Arbuckle). Then altimeter A is kept at the base station while altimeter B is advanced to the first field station (BnSCP 1). The two altimeters are again read simultaneously, and the corrected difference is applied to the base station (Arbuckle) height to give the height of the first field station (BnSCP 1). Then altimeter A is taken from the base station (Arbuckle) to the second field station (BnSCP 2). Altimeter B, which is still at the first field station (BnSCP 1), now becomes the base station. The altimeters are again read simultaneously, and the corrected difference is applied to the base station (BnSCP 1) height to give the height of the second field station (BnSCP 2). Altimeter B is now advanced to the third field station (BnSCP 3), and the same leapfrog procedures used with the first and second field stations are repeated. The altimeters are brought together and read at station Gruber, and a comparison correction is determined (fig. 62). The comparison correction should be made at every third or fourth station.

b. The techniques of observing are the same as those discussed in paragraph 188.

c. Recordings are made in DA Form 5-72. Altimeter A recorder's notes are shown in

figure 60. Altimeter B recorder's notes are shown in figure 61. Both wet and dry bulb temperatures at the time of each altimeter reading will be recorded for altimeter A. Comparison adjustment and adjusted scale readings for each observation will be determined for altimeter B (par. 191). The following is recorded for both altimeters A and B—

- (1) Station at which observation is made.
- (2) Time of observation.
- (3) Instrument temperature.
- (4) Scale reading.
- (5) Instrument temperature correction (par. 190).
- (6) Corrected scale reading (par. 190).

d. The recording and computation of the leapfrog method is the same as for the single-base method except—

- (1) In the single-base method, the base station altimeter remains at one base station during the survey. In the leapfrog method, altimeter A starts off at the base station. Altimeter B advances to the first field station and acts as the field altimeter. Altimeter A advances to the second field station and acts as the field altimeter at which

COMPUTATION - ALTIMETRIC HEIGHT (SINGLE-BASE OR LEAPFROG METHOD)									
LINE DESIGNATION		Base Station Top-Range - Osage - Cherokee						SHEET 1 OF 1 SHEETS	
FIELD STATION NAME		Time	0550	0615	0630				
		Range	Osage	Cherokee					
1	FIELD STATION DRY BULB TEMPERATURE READING (°)								
2	BASE STATION DRY BULB TEMPERATURE READING (°)	88	89	90					
3	ALGEBRAIC SUM (1) AND (2) (°)								
4	½ OF (3) (°)								
5	FIELD STATION WET BULB TEMPERATURE READING								
6	BASE STATION WET BULB TEMPERATURE READING	76	77	77					
7	(5) + (6)								
8	½ OF (7)								
9	FIELD STATION ADJUSTED SCALE READING	721.9	711.0	690.2					
10	BASE STATION SCALE READING	602.5	605.1	605.7					
11	IF (9) IS MORE THAN (10), USE (9) - (10), SIGN (+). IF (9) IS LESS THAN (10), USE (10) - (9), SIGN (-).	(+) 119.4	(+) 105.9	(+) 84.5					
12	CORRECTION FACTOR FROM: TABLE I TABLE II (°) TABLE III (°) HEIGHT CORRECTION FACTOR (I + II + III)	1.085	1.087	1.089					
13	LOG (12)	0.035 43	0.036 23	0.037 03					
14	LOG (11)	2.077 00	2.024 90	1.926 86					
15	(13) + (14)	2.112 43	2.061 13	1.963 89					
16	KNOWN HEIGHT OF BASE STATION	380.1	380.1	380.1					
17	HUMBEE HAVING LOG (15) (Use same sign as (11))	(-) 129.5	(-) 115.1	(-) 92.0					
18	ALGEBRAIC SUM (16) AND (17) = HEIGHT OF FIELD STATION	509.6	495.2	472.1					
COMPUTER		Bowden			CHECKER		Nelson		
					DATE		20 July 60		

DA FORM 6-27

EDITION OF 1 OCT 57 IS OBSOLETE

Figure 57. Computations, single-base method.

time altimeter B remains at the first field station acting now as the base station. Thus altimeters A and B alternate as the base and field station (fig. 59).

- (2) In the single-base method, the wet and dry bulb temperatures are recorded at the time of each observation of the base station. In the leapfrog method, altimeter A will record the wet and dry bulb temperature at the time of each observation regardless of whether it is designated base or field station.
- (3) In the single-base method, the comparison adjustment is always made on the corrected scale readings of the field station altimeter. In the leapfrog method, the comparison adjustment is always made on the corrected scale readings of altimeter B regardless of

whether it is designated base or field station.

e. In the leapfrog method computations are made on DA Form 6-27 (fig. 63), the same form which is used for single-base computations. Data used in figure 63 is taken from sequence of observations (fig. 59), altimeter A recorder's notes (fig. 60), altimeter B recorder's notes (fig. 61), and comparison adjustment graph (fig. 62).

f. The survey between stations where comparison observations are made is referred to as a "leg"; i.e., FIRST LEG (figs. 59 and 62).

196. When Used

a. Altimetry is used in the determination of height, when trigonometric height determination is not feasible. The situation may exist when, because of heavy fog, optical observation cannot be made. Under these circumstances,

GIVEN		RESULTS	
FOR SINGLE-BASE METHOD: For each field station, altimeter scale reading at base station and adjusted scale reading at field station (taken at same time); dry bulb temperature and wet bulb temperature at base station and field station (temperature at base station interpolated in time of readings at field station); height of base station. FOR LEAFPROG METHOD: For each leg, altimeter scale reading at base station and adjusted scale reading at first field station (taken at same time); dry bulb temperature and wet bulb temperature at base station and first field station (taken at same time), height of base station. Adjusted scale reading at first field station (base station for second half of leg) and altimeter scale reading at second field station (taken at same time); dry bulb temperature and wet bulb temperature at first and second field stations (taken at same time).		FOR SINGLE-BASE METHOD: It can be expected that heights determined will have a maximum error of 4 meters and an average error of 1 1/2 meters when observations using standard equipment are made as prescribed. FOR LEAFPROG METHOD: It can be expected that heights determined will have a maximum error of 2 meters and an average error of 1/2 meter when observations using standard equipment are made as prescribed.	
GUIDE		FORMULA	
FOR LEAFPROG METHOD: Heights of base station for each field station except the first field station is height computed for previous field station. FOR BOTH METHODS: Use known heights to nearest one-tenth meter. Convert known height in meters when given in feet or yards. Use logarithms in five places. When known height of base station in step (16) is below sea level, use step (16) as a negative value and proceed with computation. Refer to TM 8-200 for additional information.		$D = C(B - A) + Z \text{ Corrected}$ A = base station adjusted scale reading B = field station adjusted scale reading C = height correction factor D = height of field station Z = known height of base station	

HEIGHT CONVERSION - BASE STATION			
FEET TO METERS		YARDS TO METERS	
	BASE STATION		BASE STATION
1	HEIGHT IN FEET	1	HEIGHT IN YARDS
2	LOG OF HEIGHT	2	LOG OF HEIGHT
3	LOG CONVERSION FACTOR	3	LOG CONVERSION FACTOR
4	(2) + (3)	4	(2) + (3)
5	NUMBER HAVING LOG (4) = HEIGHT IN METERS	5	NUMBER HAVING LOG (4) = HEIGHT IN METERS

Figure 58. Instructions for use of DA Form 6-27.

DESIGNATION		DATE		19	
ARBUCKLE	BW SCP.1	BW SCP.2	BW SCP.3	GRUBER	
A 905	COMPARISON				
B 905					
AB 930	BF 0930			FIRST LEG	
	BB 0950	AF 0950			
		AB 1050	BF 1050		
			BB 1130	AF 1130	
				A 1155	COMPARISON
				B 1155	
A STARTING STATION BASE ALTIMETER					
B STARTING STATION FIELD ALTIMETER					
AB "A" ALTIMETER WHEN USED AS BASE ALTIMETER					
AF "A" ALTIMETER WHEN USED AS FIELD ALTIMETER					
BB "B" ALTIMETER WHEN USED AS BASE ALTIMETER					
BF "B" ALTIMETER WHEN USED AS FIELD ALTIMETER					

Figure 59. Recorder's notes for sequence of observations, leapfrog method.

A ALTIMETER

DESIGNATION <u>ALTIMETRY LEAPFROG</u> DATE <u>19</u>					
STATION	TIME	INST TEMP	SCALE READING	INST TEMP CORRECTION	CORRECTED SCALE READING
ARBUCKLE	1505	81	712.0	+ .2	712.2
ARBUCKLE	1530	82	712.5	+ .2	712.7
Bn SCP-2	1550	85	688.0	+ .3	688.3
Bn SCP-2	1650	88	687.5	+ .4	687.9
GRUBER	1730	86	790.0	+ .3	790.3
GRUBER	1755	86	790.0	+ .3	790.3

TEMPERATURE				REMARKS	
DRY	WET				
79	72			10 MILE GUSTY WIND	
79	74				
82	74				
84	74				

Figure 60. Altimeter A recorder's notes for altimetry (leapfrog).

B ALTIMETER

DESIGNATION <u>ALTIMETRY LEAPFROG</u> DATE <u>19</u>					
STATION	TIME	INST TEMP	SCALE READING	INST SCALE READING	CORRECTED SCALE READING
ARBUCKLE	1505	81	710.0	+ .5	710.5
Bn SCP-1	1530	82	702.0	+ .6	702.6
Bn SCP-1	1550	82	702.5	+ .6	703.1
Bn SCP-3	1650	84	691.0	+ .7	691.7
Bn SCP-3	1730	87	690.0	+ 1.0	691.0
GRUBER	1755	87	790.0	+ 1.0	791.0

COMPARATIVE ADJUSTMENT	ADJUSTED SCALE READING				
+ 1.6	704.2				
+ 1.4	704.5				
+ 1.1	692.8				
+ .8	691.8				

Figure 61. Altimeter B recorder's notes for altimetry (leapfrog).

the horizontal location of a station may be determined by trilateration and the height may be determined by altimetry.

b. The single-base method should be used for

height determination in a small area with the base station centrally located if possible.

c. The leapfrog method should be used for extending height over a large area.

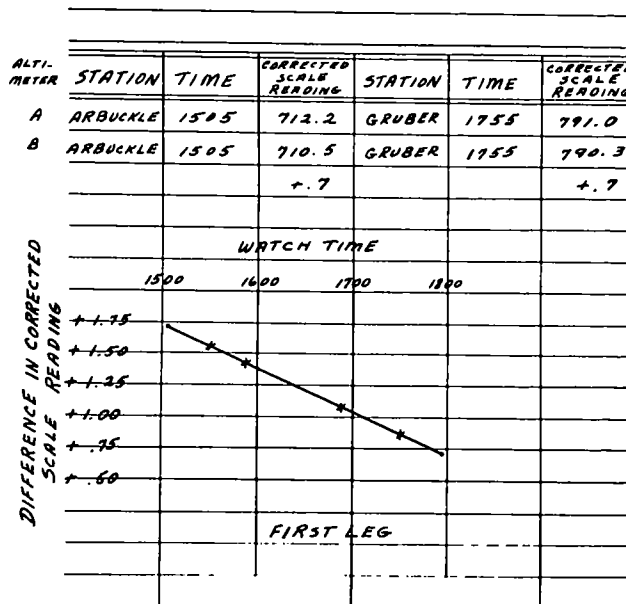


Figure 62. Comparison adjustment graph (leapfrog).

COMPUTATION - ALTIMETRIC HEIGHT (SIMPLE-BASE OR LEAPFROG METHOD)									
LINE DESIGNATION <i>Base Station Arbuckle - Bn SCP1 - Bn SCP2 - Bn SCP3 - Gruber</i>								SHEET 1 OF 1 SHEETS	
TIME OF OBSERVATION		1530	1550	1650	1730				
FIELD STATION NAME		Bn SCP1	Bn SCP2	Wolf	Gruber				
1	FIELD STATION DRY BULB TEMPERATURE READING (°)								
2	BASE STATION DRY BULB TEMPERATURE READING (°)	79	79	82	84				
3	ALOMERIC SUM (1) AND (2)								
4	1/2 OF (3)								
5	FIELD STATION WET BULB TEMPERATURE READING								
6	BASE STATION WET BULB TEMPERATURE READING	72	74	74	74				
7	(6) ÷ (4)								
8	1/2 OF (7)								
9	FIELD STATION ADJUSTED SCALE READING	704.2	688.3	692.8	790.3				
10	BASE STATION CORRECTED SCALE READING	718.7	704.5	687.9	691.8				
11	IF (9) IS MORE THAN (10), USE (9) - (10), SIGN (+), IF (9) IS LESS THAN (10), USE (10) - (9), SIGN (-).	704.2	688.3						
12	CORRECTION FACTOR FROM: TABLE I (±), TABLE II (±), TABLE III (±)	1.066	1.067	1.073	1.076				
13	RIGHT CORRECTION FACTOR (1 ÷ 12 ÷ 11)								
14	LOG (12)	0.02776	0.02816	0.03060	0.03181				
15	LOG (11)	0.92942	1.20952	0.69020	1.99344				
16	(15) ÷ (14)	0.95718	1.23768	0.72080	2.02525				
17	KNOWN HEIGHT OF BASE STATION	405.1	396.0	378.7	384.0				
18	NUMBER HAVING LOG (16)		17.3	5.2	105.9				
19	ALOMERIC SUM (14) AND (17) = HEIGHT OF FIELD STATION	396.0	378.7	384.0	489.9				
COMPUTER		<i>Nelson</i>				CHECKER		<i>Bowden</i>	
						DATE		<i>22 July 60</i>	

DA FORM 6-27

EDITION OF 1 OCT 52 IS OBSOLETE

Figure 63. Computations, leapfrog method.

CHAPTER 13

FIELD NOTES

197. General

a. Field notes are maintained by the recorder. They should contain a complete record of all measurements made during the progress of the survey. Clarifying sketches and descriptions are also made.

b. All entries are printed neatly and legibly with a sharp, hard lead pencil (4H or harder), with enough pressure to insure permanency. No erasures are allowed. When data has been entered erroneously, it is corrected by lining through the incorrect data with a single line and placing the correct entry above it. Entire pages that are not to be used are lined out by diagonal lines between opposite page corners and are marked with the word VOID in large letters.

c. The recorder accompanies the instrument operator. He records the angles and distances measured during the survey. He records the data in the field notebook as it is announced to him and then reads it back to insure the correctness of the data. In surveys performed to an accuracy of fifth-order or 1:500, the recorder checks the distances measured by the tape-man by pacing. In order to readily identify that data to be furnished to the computers, the recorder circles those values in the field notebook. He then gives the required data to the computers upon request. In addition to the measured data, the recorder makes appropriate entries on each numbered page under the *remarks* section. This includes information pertinent to the survey and a sketch showing the points for which data are recorded on that page. The sketch should be drawn roughly to scale and should include an arrow indicating approximate grid north. A straightedge and protractor should be used in making the

sketch. The chief of party will initial each numbered page after checking the data entered on that page.

d. Figure 64 is an example of the data placed on the flyleaf of the field notebook.

e. Figure 65 is an example of the index which should be placed on the first two numbered pages of the field notebook.

f. Figure 66 shows the three sections of which each numbered page consists. Note that the facing pages of the book comprise one numbered page. The heading will include such information as type of survey, date, weather, type and serial number of instrument and names of the chief of party, instrument operator, tapemen, and recorder as appropriate.

DEPARTMENT OF THE ARMY
CORPS OF ENGINEERS

LEVEL, TRANSIT AND GENERAL SURVEY
RECORD BOOK

1ST HOW BN 1ST ARTY
LOCALITY

ADVANCED UNIT TRAINING
PROJECT

BOOK 1 OF 3

0.2 MIL THEODOLITE (T/6) NR 1380
INSTRUMENT

SFC T.L. BROWN
CHIEF OF PARTY

Figure 64. Example of data placed on flyleaf of field notebook.

[illegible]

			Description & Sketch
--	--	--	-------------------------

206. Astronomic Field Notes

b. Figure 77 is an example of entries made by the recorder for observations made on a

c. Figure 78 is an example of entries made by the recorder at the master station and figure 79 is an example of entries made by the recorder at a flank station during a simultaneous observation.

DESIGNATION Position Area Survey DATE 15 Jul 19 60

Station	R	Horizontal 2 miles	Vertical 2 miles	Corrected Vertical	Distance Meters
Az MK	1	1675.0	+ 5.0	+ 8.0	
Bn SCP	2	3350.5	+ 5.5	+ 8.5	
TS-1	Mn 3	(1675.2)		(+ 8.2)	(158.32)
Bn SCP	1	4703.0			
		4706.0	- 9.0	- 6.0	
TS-1	2	3006.5	- 9.5	- 6.5	
OS "A"	Mn 4	(4703.2)		(- 6.2)	(97.40)
TS-1	1	3001.5	+ 7.5	+ 10.5	
OS "A"	2	6002.5	+ 7.5	+ 10.5	
"A" Cen	Mn 4	(3001.2)		(+ 10.5)	(92.46)
TS-1	1	4791.0	+ 1.5	+ 4.5	
OS "A"	2	3182.0	+ 2.0	+ 5.0	
TS-2	Mn 4	(4791.0)		(+ 4.8)	(115.32)
OS "A"	1	4435.5	- 8.5	- 5.5	
TS-2	2	2471.5	- 9.5	- 6.5	
Bn SCP	Mn 4	(4435.8)		(- 6.0)	(118.78)
TS-2	1	3594.0			
Bn SCP	2	788.0			
Az MK	Mn 4	(3594.0)			

Chief of Party: Sgt Brown
Weather: Clear-Hot Observer: Sgt Jones Tape: Pfc Benton
Instrument No: M2 #1789 Recorder: Cpl Smith
Pfc Kunkle

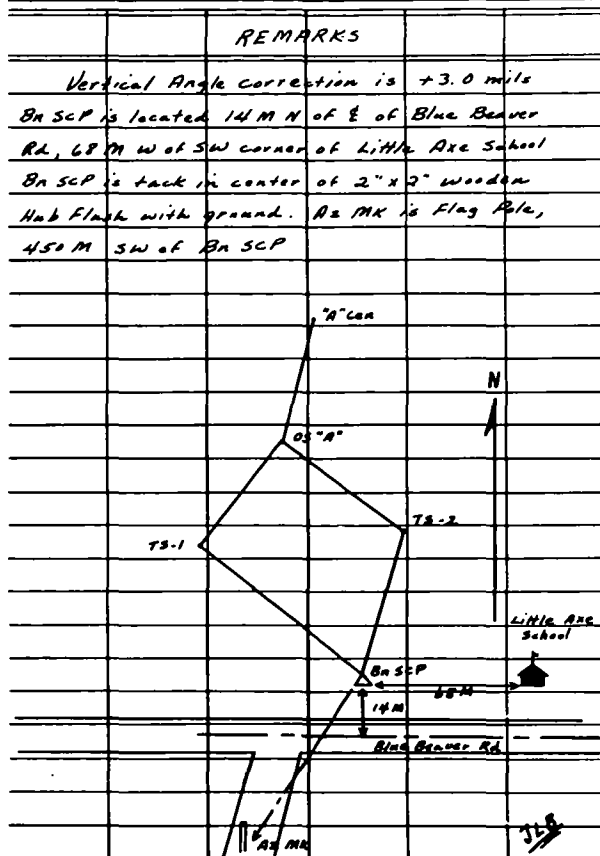


Figure 67. Recorder's notes for 1:500 (aiming circle) traverse.

Station	T	Horizontal ± Mils	Mean	Vertical Reading	Vertical ± Mils
Az MK	D	0001.0			
	R	3201.0	0001.0		
Bn SCP	Mn ±	(942.2)			(+11.5)
OS "B"	D	943.1		1588.5	+11.5
	R	4143.2	943.2	4811.5	+11.5
Bn SCP	D	0001.0			
	R	3201.0	0001.0		
OS "B"	Mn ±	(1585.1)			(-11.5)
"B" Con	D	1586.1		1611.4	-11.4
	R	4786.1	1586.1	4788.4	-11.4 -11.6
OS "B"	Mn ±	(1920.5)			(+14.1)
Sta Mac	D	3406.5		1585.9	+14.1
	R	206.7	3406.6	4814.1	+14.1
OS "B"	D	0001.0			
	R	3201.0	0001.0		
Sta Mac	Mn ±	(1492.2)			
Az MK	D	1493.1			
	R	4693.2	1493.2		

Chief of Party: Sgt Brown
Weather: Windy - Cool Observer: Sgt Jones Tape: Pfc Benton
Instrument Nr: T16[#] 5459 Recorder: Cpl Smith Pfc Kunkke

Distance Meters	REMARKS
	Bn SCP is located 3.2 miles W of BM 189 and is 21 M
485.73	N of E West Rd Bn SCP is tack in 2" x 2" wooden hub flush with ground and is marked with witness stake. Azimuth Mark is station ZEB, located on ZEB ridge and marked with a Quad Marker.
89.34	
365.01	

Figure 69. Recorder's notes for fifth-order (T16 theodolite) traverse.

Station	T	Horizontal			Mn	Vertical		
		"	'	"		"	'	"
Kiowa	D	0	00	30				
	R	180	00	33	32			
Dodge	Z	179	09	58				
TS 1	D	179	10	28		88	50	33
	R	359	10	32	30	271	09	22
Dodge	D	0	00	43				
	R	180	00	45	44			
TS-1	Z	165	33	44				
TS-2	D	165	34	27		91	03	47
	R	345	34	30	28	268	56	16

Chief of Party: Sgt Brown
Weather: Clear-Cool Observer: Sgt Jones Tape: Pfc Benton
Instrument Nr: Tz #1891 Recorder: Cpl Smith
Pfc Kunkle

Vertical $\frac{1}{2}$	Distance Meters	REMARKS
		station Dodge is located in North Arbuckle Area,
+1 09 24	672.10	Ft. Sill Military Reservation, 0.8 miles W of Bald Ridge
+1 09 27	672.12	Range central on highest
+1 09 22	672.08	point of Grassy Hill. Station is 4 M W of $\frac{1}{2}$ N-S Rd, 5 M N of $\frac{1}{2}$ E-W Rd, Marked by 1" pipe in concrete flush
-1 03 46	537.92	with ground and 15 white wooden Quad marker. Az MK
-1 03 47	537.88	is Quad marker on Kiowa
-1 03 44	537.97	N/H 2200 M SW of station Dodge.

Figure 70. Recorder's notes for fourth-order (T2 theodolite) traverse.

DESIGNATION TRIANGULATION DATE 15 JUL 19 59

STATION	R	HORIZONTAL X (M)	MEASURED VERT. Δ (M)	CORRECTED VERT. Δ (M)	DISTANCES METERS
AZ. MK.	1	1358.0			
BALL	2	2715.5			
RED	MN. Δ	(1357.8)			
RED	1	973.0	+05.5	+07.7	851.25
BALL	2	1946.0	+05.0	+07.2	851.37
MET	MN. Δ	(973.0)	(+05.2)	(+07.4)	(851.31)
MET	1	1217.5	-03.5	-01.3	
RED	2	2434.5	-04.0	-01.8	
BALL	MN. Δ	(1217.2)	(-03.8)	(-01.6)	
BALL	1	1009.0	-01.0	+1.2	
MET	2	2018.5	-01.0	+1.2	
RED	MN. Δ	(1009.2)	(-01.0)	(+1.2)	

CHIEF OF PARTY: SGT. BIRNBAUM
 WEATHER: CLEAR-HOT OBSERVER: SGT. JONES
 RECORDER: CPL. SMITH
 INSTRUMENT NR.: M2 #1789 TAPE: PFC MILLER PFC DITTO

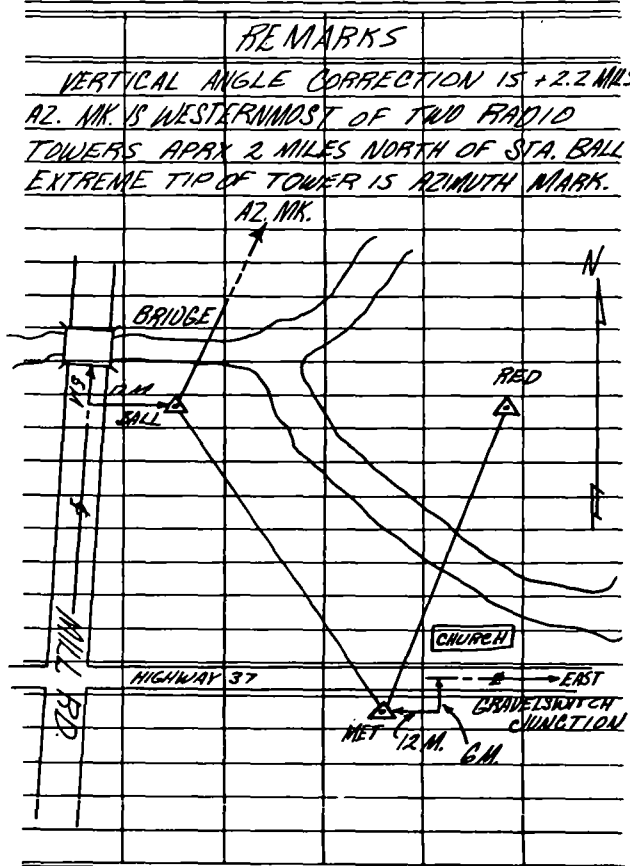


Figure 71. Recorder's notes for 1:500 (aiming circle) triangulation

DESIGNATION TRIANGULATION DATE 21 JUL 19 60

Station	T	R	Horizontal $\frac{1}{2}$			Vertical $\frac{1}{2}$		
MB-4	D	1	96	56	00	+0	06	
Buck	R	2	193	52	20	+0	06	
Monster	Mn	3	96	56	10			
	Adj	3	96	56	03	+0	06	00
Monster	D	1	91	58	00	-0	03	
Buck	R	2	183	55	40	-0	04	
Dodge	Mn	3	91	57	50			
	Adj	3	91	57	44	-0	03	30
Dodge	D	1	171	06	20	+0	10	
Buck	R	2	342	12	40	+0	11	
MB-4	Mn	3	171	06	20			
	Adj	3	171	06	13	+0	10	30

Weather: Cloudy-Warm Chief of Party: Sgt Brown
Observer: Sgt Jones Tape: Pfc Benton
Instrument Nr: Transit #1849 Recorder: Cpl Smith
Pfc Kanke

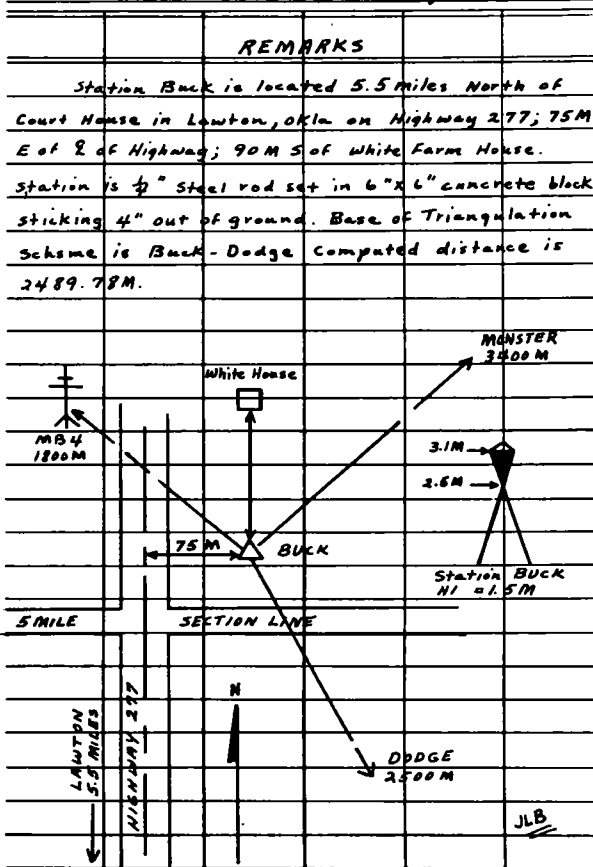


Figure 72. Recorder's notes for fifth-order (20 second transit) triangulation.

DESIGNATION TRIANGULATION DATE 24 JUL 1960

Station	T	Horizontal Δ miles	mean	Vertical reading	Vertical Δ mile
Dick	D	0001.0			
	R	3201.0	0001.0		
Tom	Mn Δ	(733.8)			(+15.6)
Harry	D	734.8		1584.4	+15.6
	R	3934.8	734.8	4815.6	+15.6
Harry	D	0001.0			
	R	3201.0	0001.0		
Dick	Mn Δ	(1091.5)			(-19.5)
Tom	D	1092.5		1619.5	-19.5
	R	4292.5	1092.5	4781.5	-19.5
Tom	D	0001.0			
	R	3201.0	0001.0		
Harry	Mn Δ	(1374.5)			(+3.9)
Dick	D	1375.5		1596.1	+3.9
	R	4575.5	1375.5	4803.9	+3.9

Weather: Clear - Warm Chief of Party: Sgt Jones
Observer: Sgt Haines

Instrument Nr: T-16 #7439 Recorder: Cpl Matt

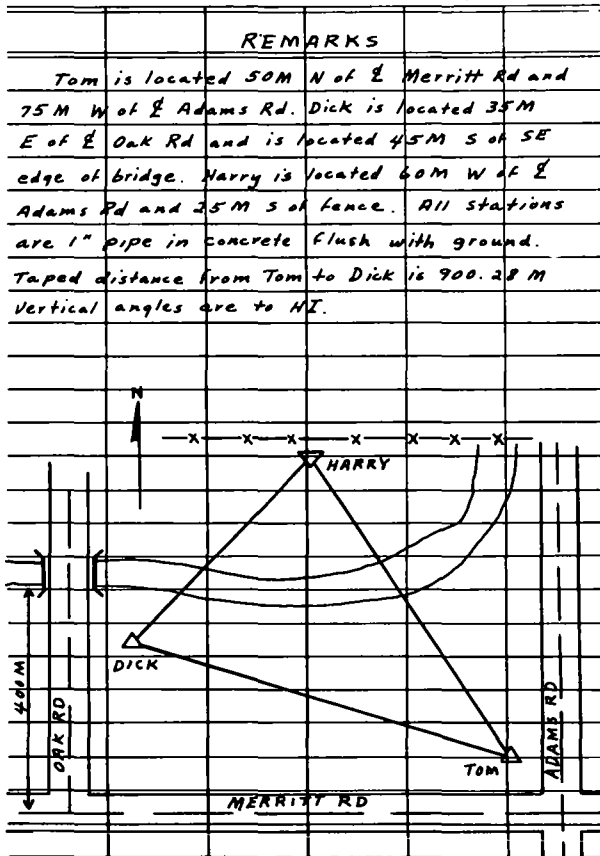


Figure 73. Recorder's notes for fifth-order (T16 theodolite) triangulation.

DESIGNATION TRIANGULATION DATE 25 JUL 19 60

Station	T	Horizontal				Vertical		
		°	'	"	Mm	°	"	
Dodge	D	0	00	20		88	09	07
	R	180	00	24	22	271	50	55
Caddo	Z	(91	12	16)				
Potato	D	91	12	37		90	03	14
	R	271	12	40	38	269	56	39
Caddo	Z	(132	46	30)				
Arbuckle	D	223	59	07		87	17	20
	R	43	59	09	08	272	42	36
Caddo	Z	(100	16	00)				
Kiowa	D	324	15	07		91	12	12
	R	144	15	10	08	268	47	52

Weather: Clear-Cool Chief of Party: Sgt Brown
Observer: Sgt Jones

Instrument Nr: T2 #1881 Recorder: Cpl Smith

Vertical	°	'	"	REMARKS
+1	50	53		First Position of
+1	50	55		Two Positions
+1	50	54		Base Length: Caddo-Dodge
				3409.41 M (BT 1)
-0	03	14		
-0	03	21		DODGE
-0	03	18		2.9 M ABOVE STA
+2	42	40		
+2	42	36		POTATO
+2	42	38		2.4 M ABOVE STA
-1	12	12		OBSERVED HI AT
-1	12	08		ARBuckle
-1	12	10		3.3 M ABOVE STA
				KIOWA
HEIGHT OF				4.8 M
SIGNAL AT				3.8 M
CADDO				2.6 M
HI = 1.5 M				ABOVE STATION

Figure 74. Recorder's notes for fourth-order (T2 theodolite) triangulation.

DESIGNATION TRIANGULATION (cont) DATE 25 JUL 19 60

Station	T	Horizontal			Mn Horizontal		
		°	'	"	°	'	"
Dodge	R	270	00	42	91	12	16
	D	90	00	45	44	91	12
Caddo	X	(91	12	17)	(91	12	16)
Potato	R	1	12	59	132	46	30
	D	181	13	03	01	132	46
Caddo	X	(132	46	30)	(132	46	30)
Arbuckle	R	133	59	30	100	16	00
	D	313	59	32	31	100	16
Caddo	X	(100	16	01)	(100	16	00)
Kiowa	R	234	15	31			
	D	54	15	34	32		

REMARKS			
SECOND POSITION			
Station Caddo is located in the South Arbuckle Area of the Ft. Sill Military Reservation, 1.6 miles S of Bald Ridge Range Central on highest point of Grassy Knoll W of Rattan Creek. Station is 1" Bronze plug set in 10"x10" concrete block flush with ground			
RM #1 is old target tank			
RM #2 is fork in trail			
RM #3 is 2" pipe sticking 1' above ground on W side of trail			

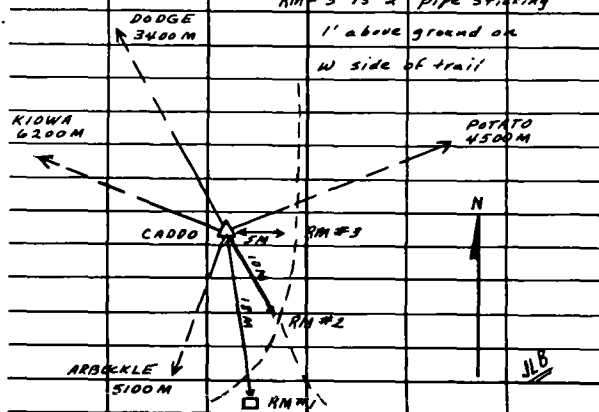


Figure 74—Continued.

SUN OBSERVATION ALTITUDE METHOD									
DESIGNATION		DATE 22 JUL 19 60							
Station	T	R	h	Time m	s	Horizontal Δ ° ' "			
Powell	1 st D	1	09	05	34	120			
Beck	1 st R	2	09	07	33	240	46	20	
Sun	Mn Δ		09	06	34	120	23	10	
Powell	2 nd D	1	09	12	24	121			
Beck	2 nd R	2	09	13	44	243	10	00	
Sun	Mn Δ		09	13	04	121	35	00	
Powell	3 rd D	1	09	17	30	122			
Beck	3 rd R	2	09	18	38	245	03	00	
Sun	Mn Δ		09	18	04	122	31	30	

Weather: Clear - Warm		Chief of Party: Sgt Brown	
Observer: Sgt Jones			
Instrument Nr: Transit #1849		Recorder: Cpl Smith	
Vertical Δ ° ' "		REMARKS	
36 40		Latitude 34° 39' 34" N	
37 30		Longitude 98° 24' 18" W	
37 05 00		Station Beck is located on	
		Ft Sill Military Reservation on	
38 00		S slope of Gunnery Hill, 6M W of	
38 44		SW corner of Bldg 3077, 200 M W	
38 22 00		of 2 Ft Sill Blvd.	
		Station Powell is located 306M	
39 02		NW of Beck, 10M N of Motor Park	
39 41		34M W of Tank Trail. Both stations	
39 21 30		are 1/2" iron pipes in center of	
		6"x6" concrete blocks projecting	
		6" out of ground. Temp 85°F	
		Watch 16 ^s slow	
		Austin Rd	
		6M 3077 3078	
		BECK	

Figure 75. Recorder's notes for fifth-order (20-second transit) observations on the sun, altitude method.

SUN OBSERVATION ALTITUDE METHOD						
DESIGNATION			DATE	19 JUL	1960	
Station	T	h	m	s	Horizontal X Mils	Mean
WT	D				0001.0	
	R				3201.0	0001.0
SD 260	Mn X	08	30	30	3823.8	
Sun	D	08	28	30	3821.1	
	R	08	32	30	628.4	3824.8
WT	D	08			0001.0	
	R				3200.9	0001.0
SD 260	Mn X	08	36	00	3846.4	
Sun	D	08	34	00	3845.7	
	R	08	38	00	649.2	3847.4
WT	D				0001.0	
	R				3201.0	0001.0
SD 260	Mn X	08	50	00	3881.2	
Sun	D	08	48	00	3879.5	
	R	08	52	00	684.8	3882.2

Weather: Clear - Warm		Chief of Party: Sgt Brown	
Instrument Nr: T16 #5459		Observer: Sgt Jones	
Recorder: Cpl Smith			
Vertical Reading	Vertical X Mils	REMARKS	
		Latitude 34° 39' 48" N	
		Longitude 98° 24' 18" W	
	+551.5	Temp 85°F	
		Station SD 260 is	
1053.2	+546.8	located 10M S of Bldg	
5356.2	+556.2	3077. Station is 0.30	
		cal cartridge case set	
		in triangular concrete	
		block. Azimuth mark	
	+581.1	is shaft supporting light	
		on top of OCS water tower.	
1020.9	+579.1		
5383.1	+583.1		
	+623.7		
979.5	+620.5		
5426.9	+626.9		

Figure 76. Recorder's notes for fifth-order (T16 theodolite) observations on the sun, altitude method.

STAR OBSERVATION
DESIGNATION HOOR ANGLE METHOD DATE 27 JUL 19 60

Station	T	h	m	s	Horizontal ° ' "	Mn
TS-1	D				0 00 58	
	R				180 01 14 06	
Don	Mn	22	14	14	358 25 38	
Polaris	D	22	13	12	358 26 15	
	R	22	15	15	178 27 12 44	
TS-1	D				0 00 22	
	R				180 00 46 34	
Don	Mn	22	19	41	358 27 14	
Polaris	D	22	18	48	358 29 20	
	R	22	20	34	178 28 16 48	
TS-1	D				0 00 17	
	R				180 00 42 30	
Don	Mn	22	25	00	358 28 50	
Polaris	D	22	24	16	358 28 58	
	R	22	25	44	178 29 41 20	

Weather: Clear-Cool Chief of Party: Sgt Brown
Observer: Sgt Jones
Instrument Nr: T2 #1881 Recorder: Cpl Smith

REMARKS
Station Don is located on N slope of Misery Hill 35M E of E Ft Sill Blvd and 200M S of Intersection Ft Sill Blvd and Ringold Rd.
Latitude 34°41'43" N - Longitude 98°20'34" W
A2 MK is TS-1 located 100M E of E Ft Sill Blvd and 90M S of E Sheridan Rd
Both stations are tacks in 2"x2" wooden hubs flush with ground Watch 073 East

Figure 77. Recorder's notes for fourth-order (T2 theodolite) observations on a star, hour angle method.

DESIGNATION SIMULTANEOUS OBSERVATION DATE 28 JUL 19 60

Station	T	Horizontal			Vertical		
		°	'	"	°	'	"
WT	D	0	00	29			
	R	180	00	30	30		
Adams	Mn	340	16	49			
Sun	to D	340	12	37	67	19	57
	to R	160	22	01	19	29	13

Weather: Cool-Clear Chief of Party: Sgt Brown
Observer: Sgt Jones

Instrument No: T2 #1881 Recorder: Cpl Smith

Vertical	Remarks
°	'
"	
	Station Adams is master
	station is located 15M SW
22 08 38	of Junction Dump Rd and E1
	Rd. Station is 1" pipe set in
22 40 03	6"x6" concrete block flush
21 37 13	with ground.
	A2 MK is lightning rod on
	top of water tower 1000 M SW
	of Adams.
	Computation of Az to Sun:
	Az Adams to WT 242° 13' 34"
	Az WT-Adams-Sun 340° 16' 49"
	582° 30' 23"
	- 360
	Az Adams to Sun: 222° 30' 23"

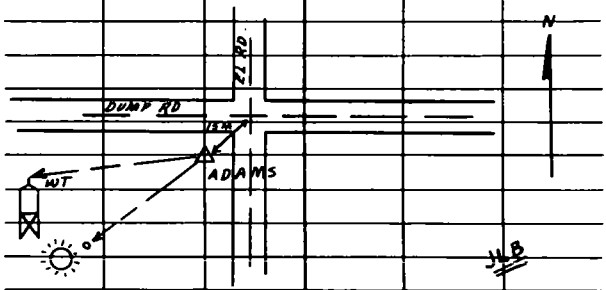


Figure 78. Recorder's notes made at the master station for a simultaneous observation.

PART THREE
SURVEY METHODS AND COMPUTATIONS
CHAPTER 14
TRAVERSE

Section I. PROCEDURES

207. General

A traverse is a succession of straight lines, called traverse legs, connecting a succession of established points, called traverse stations (TS) (fig. 80). Distances along the line between these points are determined by direct measurement, either with a 30-meter steel tape or by other distance measuring devices. At each traverse station, a horizontal angular measurement is taken and used to determine the azimuth of the next traverse leg. A vertical angle is also measured and used to compute the height of the next station. In artillery surveys, the angular measurements are made by using one of four instruments, depending on the accuracy required and the echelon at which the traverse is conducted. These instruments are the aiming circle, the T16 theodolite, the T2 theodolite, and the transit.

208. Types of Traverse

There are basically three types of traverse which are used. These are open traverse, closed traverse (two kinds: closure on second known point and closure on starting point), and directional traverse.

a. Open Traverse. An open traverse is any traverse which starts at a point of known coordinates, proceeds to its destination, and does not close. The open traverse is considered the least desirable type of traverse because it provides no check on fieldwork. For this reason, traverses are never deliberately left open and are always closed as soon as possible. Open traverses are used only when time does not allow a closure on a known point.

b. Closed Traverse on Starting Point. A closed traverse on the starting point is a traverse which begins at a point of known

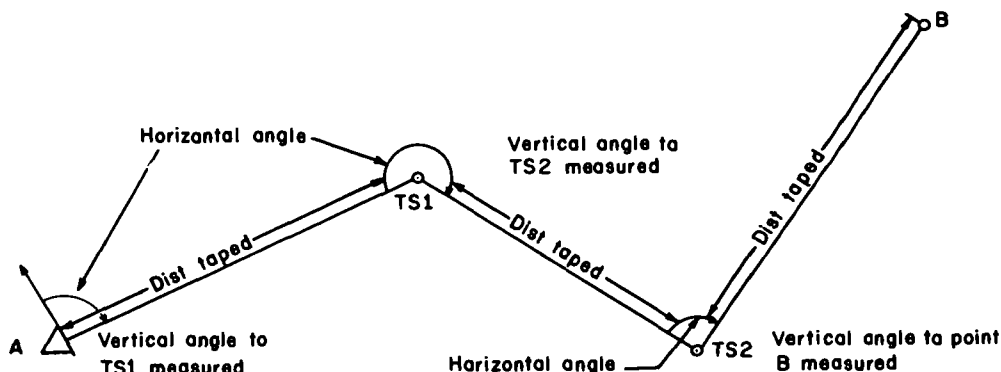


Figure 80. Schematic diagram showing a traverse.

coordinates, moves to its point of destination, and returns to and terminates at the starting point. This type of traverse is considered the second best and is used when both time for survey and limited control are considerations. It will provide checks on fieldwork and computations and will afford a basis for comparison to determine the accuracy of the work performed.

c. Closed Traverse on Second Known Point.

A closed traverse on a second known point is a traverse which begins from a point of known coordinates, moves to its destination, and then continues to terminate at a second point of known coordinates. It is desirable that the point on which the traverse is closed be a point established to an accuracy at least one degree higher than the traverse being performed. A closing point established to same degree of accuracy as the traverse being performed is acceptable. (One exception to this is a traverse started from a map inspected point. Little or no value is obtained from using a map inspected point as an additional point for closure.) A traverse closed on a second known point is the most preferred type of traverse. It will provide checks on fieldwork, computations, and the starting coordinates as well as afford a basis for comparison to determine the accuracy of the work performed.

d. Directional Traverse. A directional traverse is a type of traverse which extends directional control only. This type of traverse can be either open or closed; if open, the directional traverse should be closed at the earliest opportunity. It can be closed either on the starting direction, or another direction of equal or greater accuracy, by astronomic observation, or by an azimuth gyro surveying instrument. Since direction is the most critical element of artillery survey control, it is sometimes necessary at lower echelons to map spot battery locations and extend direction only.

209. Organization of Traverse Parties

The number of personnel authorized to perform survey will depend on the unit's table of organization and equipment (TOE). The organization of these persons into a traverse party and the duties assigned to each member will depend on the unit's standing operating procedure (SOP). The organization and duties

of traverse party members are based on the functional requirements of a traverse. See appendix III for detailed description of duties of individuals.

a. Eight-Man Traverse Party.

- (1) *Chief of party.* The chief of party selects and marks the locations for the traverse stations and supervises the work of the other members of the party. He also assists the survey officer in the reconnaissance and planning of the survey.
- (2) *Instrument operator.* The instrument operator measures the horizontal and vertical angles at each traverse station.
- (3) *Recorder.* The recorder keeps the field notes for the party in a field notebook. He records the angles measured by the instrument operator, the distance measured by the tapemen, and all other data pertaining to the survey. The recorder is normally the party member designated to check the taped distances by pacing between traverse stations.
- (4) *Computer.* Two computers compute the grid coordinates and height of each traverse station as the traverse progresses. The computers work independently and check their results with each other.
- (5) *Tapeman.* Two tapemen measure the distances from one traverse station to the next. Each tapeman keeps a record of the distances taped. The tapemen compare their recorded distances before reporting the measured distance to the recorder.
- (6) *Rodman.* The rodman assists the chief of party in marking the traverse stations, removes the range pole from the rear station when signaled by the instrument operator and moves it forward to the next traverse station.

b. Fourth-Order Traverse Party. The fourth-order traverse party consists of 10 men. There are two types of fourth-order traverse parties:

- (1) *Ten-man traverse party.* This party is basically the same as the eight-man traverse party with two additional

tapemen who form a second taping team.

- (2) *Tellurometer traverse party.* This party is equipped with three T2 theodolites and one tellurometer set, which includes one master and two remote units. The personnel are organized as follows: one chief of party, three instrument operators, three recorders, two computers, and one rodman.

c. Reduced Strength Party. Often the authorized number of men are not available to perform the traverse. Under such circumstances, other members of the survey party may be required to perform more than one function. Shortages in personnel will seldom affect the jobs of the instrument operator or the tapemen, since these two functions must be performed if a traverse is to be conducted. Shortages will be apparent in the duties of rodman, computer, and recorder. If the party is short one rodman, the chief of party will perform the duties of the rodman in addition to his own duties. If the party is short one computer, the recorder will also compute. If there is no recorder, the instrument operator will act as his own recorder. If three or more men are absent from the party, the fieldwork is completed, and computations are performed later by designated personnel. Organization of a reduced-strength party is not bound by strict rules; however, for a party to function when personnel shortages exist, the party members must be trained to operate interchangeably.

210. Night Traverse

Many times the artillery surveyor will be forced to survey at night to accomplish his mission. This can be done by a modification of daylight techniques and organization. However, night traverses require more work, more training, more personnel, and more coordination.

a. Equipment Required for Night Traverse. The same equipment used in a daytime traverse is also used in a night traverse with the addition of the necessary lighting equipment. Included in this lighting equipment are flashlights for all personnel and two aiming post lights for each range pole. If aiming post lights are not available, two flashlights for each range pole will suffice. All lighting devices should be

equipped with a filter of some type to insure greater light security and to prevent undue glare in the telescope of the observing instrument when it is pointed at a station. The observing instrument should be equipped with its organic lighting equipment.

b. Personnel. The standard traverse party must be supplemented with additional personnel to enable it to function properly at night. Three additional men who are light holders accompany and assist the tapemen. When possible, a fourth man is used to assist the rodman.

c. Angle Measuring. The same procedure is used in measuring angles at night as in daylight except that at night the instrument must be equipped with a night lighting device. The instrument operator should coordinate with the rodman to insure that the lights on the range poles are placed and pointed properly and are moved to the next station when the observation is completed.

d. Recording. The recording procedures are the same as those for surveys during daylight except the recorder must be supplied with a flashlight so that he can see to record. He should record in the remarks section of the field notes anything which may have an effect on the survey, such as burned out lights, only one light on the forward station, etc.

e. Taping. For information on taping at night see paragraph 39.

f. Communications. Communications during a night traverse should be conducted by radio. However, radio is not always convenient or available and at times the survey party must resort to light signals. These light signals should be prearranged and simple. For example, the instrument operator may have to signal the rodman to raise or lower the bottom light on a range pole or inform him to move to the next station, etc. In arranging signals, the survey party should avoid waving the lights, since a waving light may easily attract the enemy's attention. Every precaution should be taken in sending light signals to avoid detection by the enemy.

211. Accuracies, Techniques, and Specifications

In artillery survey, there are three minimum accuracies which serve as standards for survey

personnel to meet in both fieldwork and computations. These accuracies are fourth-order (1:3,000), fifth-order (1:1,000), and 1:500. The term "order" includes not only position accuracy but also directional accuracy. Position accuracies are expressed as a fraction and mean that for the unit. For example, in a 1:1,000 survey, for every 1,000 meters surveyed, the allowable error is 1 meter. Fifth-order accuracy is normally performed by field artillery battalions. Fourth-order surveys are normally performed by personnel of the division artillery headquarters battery and the target acquisition battalion at corps. Since minimum accuracies have been established, certain specifications and techniques must be employed to assure the surveyor that the work he performs will produce results within the accuracy required. These specifications and techniques for traverse are as shown in appendix II.

212. Traverse Requirements

Three basic requirements for a traverse are the distance between traverse stations, the azimuth of a line between successive stations, and a vertical angle. Since the purpose of traverse is to locate points relative to each other and relative to a common grid, two other elements constituting starting data are needed. The coordinates of a starting point and an azimuth to an azimuth mark are required. They can be obtained through several means as indicated in *a* through *c* below.

a. Available Control. Starting control may be available in an existing trig list, or higher headquarters may provide data for a survey control point. An azimuth to an azimuth mark (starting direction) may be obtained by reference to a trig list, by computation from known coordinates, by astronomic observation, or by use of an azimuth gyro surveying instrument.

b. Maps. If there is no control available, map inspection may be used to determine starting coordinates and height. Starting direction may be determined by astronomic observation, by using an azimuth gyro surveying instrument, by scaling from a map or by using a declinated aiming circle.

c. Assumed. When neither maps nor control are available, the coordinates and height of the starting point may be assumed. Starting

direction may be determined by using a declinated aiming circle or by estimating from north.

213. Fieldwork

In a traverse, three traverse stations are considered of significance. These are referred to as the *rear station*, the *occupied station*, and the *forward station*. The rear station is that station from which the persons performing the traverse have just moved or a point, the azimuth to which is known. The occupied station is the station at which the party is located and over which the surveying instrument is set. The forward station is the next station in succession and constitutes the immediate destination of the party. Field measurements for the traverse are as follows:

a. Horizontal Angles. Horizontal angles are always measured at the occupied station by pointing with the instrument toward the rear station and turning the angle clockwise to the forward station. In measuring horizontal angles, the instrument is sighted always at the lowest visible point of the range pole which marks the rear and forward stations.

b. Vertical Angles. Vertical angles are measured at the occupied station to the height of instrument (HI) on the range pole at the forward station. When the distance between two successive stations in a traverse exceeds 1,000 meters (m), then the vertical angle must be measured reciprocally; i.e., the vertical angle is measured in both directions for that particular traverse leg. The purpose of this is to eliminate errors caused by curvature and refraction.

c. Distance. The distance is horizontally taped in a straight line between the occupied station and the forward station or determined using other distance measuring devices.

214. Use of the Range Pole

a. When the range pole is used, the point of the shoe at the bottom of the pole is placed on the point marking the survey station. The pole must be vertical. It must be supported, throughout observation on the point, by a man holding it or by use of a range pole tripod. A level is issued to field artillery units for insuring that the range pole is vertical. In use, the level is placed with the angular portion against the

pole with the circular level vial up. The range pole then is made vertical by centering the bubble in the level vial. The level should be checked by verifying that the bubble is centered at several points around the range pole. If the range pole is held by hand, the level should be held against the pole throughout the time that the pole is on the station. *The range pole should never be placed in a vertical position during surveying except when the pole is in use over a survey station.* This will prevent an instrument operator from measuring an incorrect angle by sighting on the pole when it is not over the station being used.

b. At night, the range poles are used in the same manner as in daylight except for the lighting devices required at the rear and forward stations. Two aiming post lights should be placed on each range pole. One of these lights should be placed on the pole at the height of instrument and the other at the lowest point visible from the instrument. Both lights should be pointed directly at the instrument. If aiming post lights are not available, flashlights may be taped or strapped to the range pole in the same manner. To insure that the lights are properly placed, the rodman should not leave the range pole until the instrument operator has indicated that the lights are visible.

215. Marking Stations

The number of stations in a traverse should be kept to a minimum. Each station must be visible from the preceding station. At each station, a stake (hub) is driven flush with the ground. The center of the top of the hub is marked by a stake tack or by marking an X to

designate the exact location of the station. At critical points, i.e., points where survey control is required or which may be used in subsequent survey operations, a reference stake is driven into the ground so that it slopes toward the hub (fig. 81). The name of the station is written with a grease pencil either on the reference stake or on a tag attached to it. To further provide ease in identification, a strip of red target cloth may be tied to the reference stake.

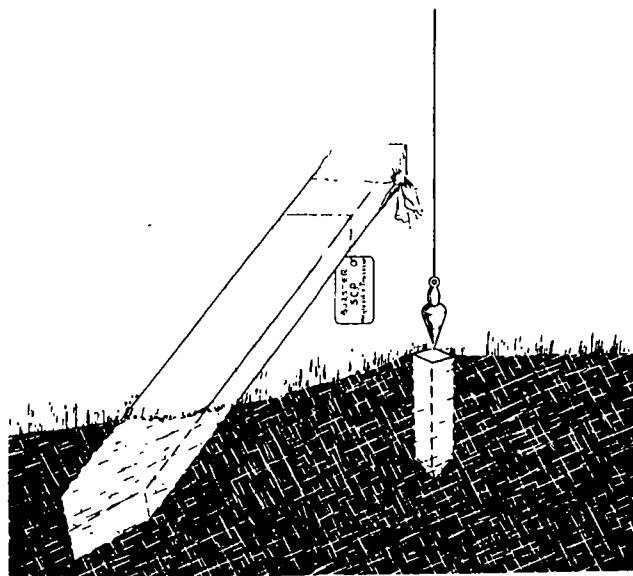


Figure 81. A survey station marked with a reference stake.

216. Traverse Field Notes

For examples of field notes on traverse, see figures 67 through 70.

Section II. COMPUTATIONS

217. Azimuth and Bearing Angle Relationship

a. The primary reason that azimuth is a requirement of a traverse is to enable the determination of a bearing angle. The bearing angle of a traverse leg, not the azimuth, is the element used in traverse computations. The azimuth of a line may be defined as the horizontal clockwise angle from a base direction. The base direction used in artillery survey is grid north. The bearing angle of a line is the

acute angle formed by the intersection of that line with a north-south line. Figure 82 illustrates the relationship between the azimuth of a line and its bearing.

b. The manner in which bearing angles are computed from a given azimuth depends on the quadrant in which that azimuth lies (fig. 83). When the azimuth is in the first quadrant, 0° – 90° (0 mils–1,600 mils), the bearing is equal to the azimuth. When the azimuth is in the second quadrant, 90° – 180° (1,600 mils–3,200

218. Coordinate Computations

a. If the coordinates of a point are known and the azimuth and distance from that point to a second point are known, the coordinates of the second point can be determined. In figure 84, the coordinates of station A are known and the coordinates of TS 1 are to be determined. The azimuth and distance from station A to TS 1 have been determined by measuring the horizontal angle $Az\ Mk-A-TS\ 1$ and by taping the distance from station A to TS 1. The grid easting and grid northing lines through both of the points are shown. To determine the coordinates of TS 1, it is necessary to add the difference in easting (dE) to the easting coordinates of station A, and the difference in northing (dN) to the northing coordinates of station A.

b. In figure 84, the traverse leg appears in the first quadrant. It is for this reason that dE and dN must be added to the easting and northing coordinates of station A. If the traverse leg were to appear in one of the other quadrants, the signs of dE and dN would change. The sign of dE and dN is determined by the quadrant in which the traverse leg lies (fig. 85).

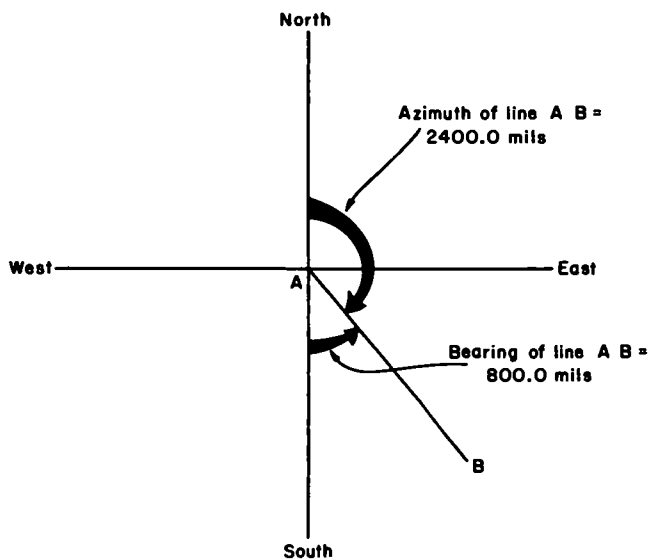


Figure 82. Sketch showing azimuth-bearing relationship.

mils), the bearing is equal to 180° (3,200 mils) minus the azimuth. When the azimuth is in the third quadrant, 180° – 270° (3,200 mils–4,800 mils), the bearing is equal to the azimuth minus 180° (3,200 mils). When the azimuth is in the fourth quadrant, 270° – 360° (4,800 mils–6,400 mils), the bearing is equal to 360° (6,400 mils) minus the azimuth.

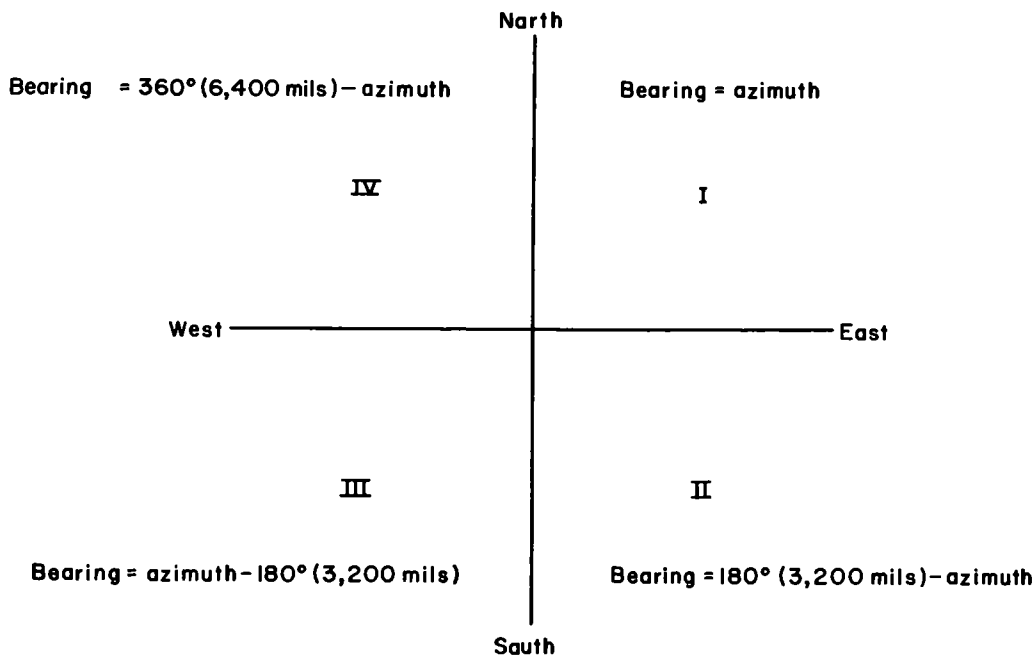


Figure 83. Sketch showing bearing angle determination.

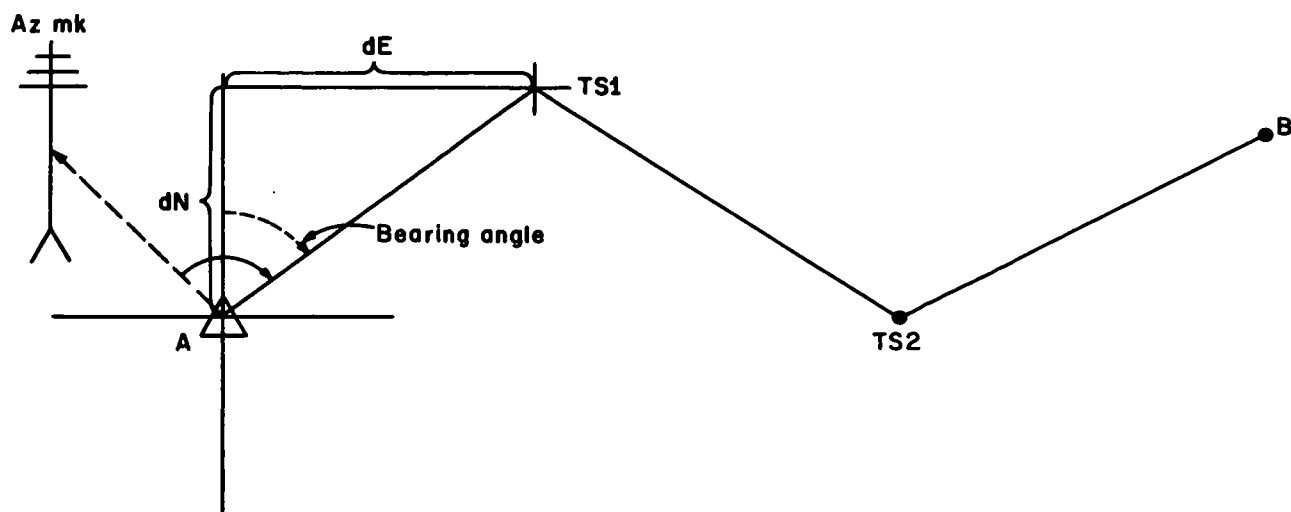


Figure 84. Schematic diagram showing dE and dN requirements.

219. Determination of dE and dN

The determination of the values of dE and dN between two points when the azimuth and distance between those points are known requires the solution of a right triangle. In figure 84, side A-TS 1 is known because it is a taped distance. The bearing angle at station A is also known, since it can readily be determined from the azimuth of station A to TS 1. Since the intersection of the north-south line through station A and the east-west line through station TS 1 forms a right angle (90° or 1,600 mils), a right triangle is created with the hypotenuse (side A-TS 1) known.

To determine dE:

$$\begin{aligned} \text{Sine of bearing angle} &= \frac{\text{opposite side}}{\text{hypotenuse}} = \frac{dE}{\text{distance}} \\ \text{or,} \\ dE &= \text{sine of bearing angle} \times \text{distance} \end{aligned}$$

To determine dN:

$$\begin{aligned} \text{Cosine of bearing angle} &= \frac{\text{Adjacent side}}{\text{hypotenuse}} = \frac{dN}{\text{distance}} \\ \text{or,} \\ dN &= \text{cosine of bearing angle} \times \text{distance} \end{aligned}$$

220. Determination of dH

In conducting a traverse, the surveyor is required to determine the height of each traverse station. This is accomplished by determining the difference in height (dH) between the occupied and the forward station. By using the

vertical angle at the occupied station and the distance from the occupied station to the forward station, the difference in height between the two can be determined by solution of a right triangle. In figure 86, the distance is the horizontal taped distance from station A to TS 1. The vertical angle at station A is the vertical angle measured to HI at station TS 1. The difference in height (dH) between the two stations is that side of the right triangle which requires solving.

To determine dH:

$$\begin{aligned} \text{Tangent of vertical angle} &= \frac{\text{opposite side}}{\text{adjacent side}} = \frac{dH}{\text{distance}} \\ \text{or,} \\ dH &= \text{tangent of vertical angle} \times \text{distance} \end{aligned}$$

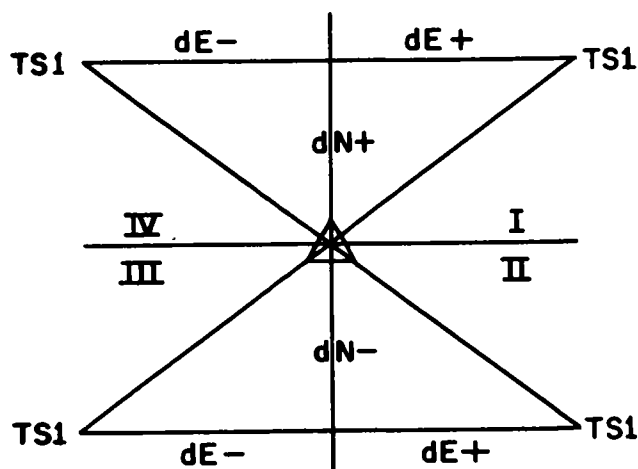


Figure 85. Quadrant-sign relationship for dE and dN.

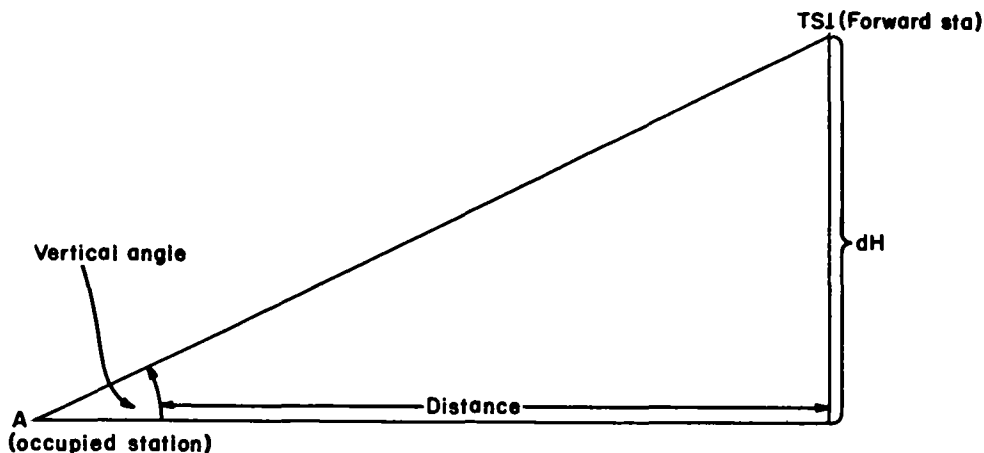


Figure 86. Schematic diagram showing right triangle for determination of dH .

221. Scale Factor

The log of the scale factor is applied to the dE and dN computations of all surveys executed to an accuracy of fourth-order. The purpose of the log scale factor is to convert ground distance to map distance when the universal traverse mercator (UTM) grid is used. This factor is not used in surveys to accuracies less than fourth-order because of the low accuracies of these surveys. The scale factor value varies with the distance of the occupied station from the central meridian of the UTM grid zone. The scale factors are given for every 10,000 meters east and west of central meridian and are shown in tabulated form on the back of DA Form 6-2. The values of the scale factor are extracted by entering the table on the back of the form (fig. 88) with the approximate easting value of the occupied station to the nearest 10,000 meters.

222. DA Form 6-2

a. DA Form 6-2 (figs. 87 and 88) is used to determine coordinates and height from azimuth, distance, and vertical angle.

b. Entries on the form are as shown in figure 87.

c. Formulas to be used are shown on the back of DA Form 6-2.

223. Reciprocal Measurement of Vertical Angles

The effects of curvature and refraction of lines of sight must be considered for traverse legs in excess of 1,000 meters. These effects

can be compensated for by reciprocal measurements of the vertical angle from each end of such a leg. *In measuring vertical angles reciprocally, the vertical angle at each end of the leg should be measured to the same height above the station (normally HI).* If this cannot be done, DA Form 6-2b (Computation—Trigonometric Heights) (fig. 90), must be used in computing the height of the forward station.

224. DA Form 6-2b

a. DA Form 6-2b (figs. 90 and 91) is used to determine heights of forward stations when the angles are measured reciprocally or non-reciprocally to different heights above the station.

b. Entries required are the vertical angles measured, height of station, heights of instrument, and heights of target.

c. The formula to be used is shown on the back of DA Form 6-2b.

225. Azimuth and Distance from Coordinates

In survey operations, it is often necessary to determine the azimuth and distance between two stations of known coordinates. Some examples of a requirement of this nature are computation of a starting azimuth for a survey when the coordinates of two intervisible points are known, computation of azimuth and length of a target area base or the base of a triangulation scheme, and computation of azimuth and distance between critical surveyed points when swinging and sliding the grid is

AZIMUTH		SIGHT	DISTANCE AND BEARING TO FORWARD STATION		COMPUTATION - COORDINATES AND HEIGHT FROM AZIMUTH, DISTANCE AND VERTICAL ANGLE (FM 6-120)										DATE
AS TO REAR STATION	STATION ANGLE		AS TO BEARING	BEARING	REAR STATION					COORDINATES					
AS TO REAR STATION	52 47 5		AS TO BEARING	2 50 5	STATION <i>Dog</i>					STATION <i>Pet</i>					132.7
STATION ANGLE	14 03 0		LOG CONV FT TO METERS	9.484 0158	LOG CONV FT TO METERS	9.484 0158	VERTICAL ANGLE	18 1	554 187.6	3 835 928.4	2.0				
Sum	66 50 0		LOG SCALE FACTOR		LOG SCALE FACTOR		LOG CONV FACTOR								
AS TO FWD STATION	2 50 5		LOG SIN BEARING	9.386 421	LOG COS BEARING	9.986 732	LOG TAN VERT ANGLE	8.249 725							
(+/-) 100'	32 00 0		DISTANCE	2.055 417	LOG DISTANCE	2.055 417	LOG DISTANCE	2.055 417							
AS TO REAR STATION	34 50 5		AS TO BEARING	60 61 3	STATION <i>TS1</i>					STATION <i>TS1</i>					134.7
STATION ANGLE	26 10 8		LOG CONV FT TO METERS	9.484 0158	LOG CONV FT TO METERS	9.484 0158	VERTICAL ANGLE	0 3	554 215.3	3 836 038.6	0.0				
Sum	60 61 3		LOG SCALE FACTOR		LOG SCALE FACTOR		LOG CONV FACTOR								
AS TO FWD STATION	60 61 3		LOG SIN BEARING	9.513 782	LOG COS BEARING	9.975 534	LOG TAN VERT ANGLE	6.469 121							
(+/-) 100'	32 00 0		DISTANCE	1.853 698	LOG DISTANCE	1.853 698	LOG DISTANCE	1.853 698							
AS TO REAR STATION	28 61 3		AS TO BEARING	16 38 8	STATION <i>TS2</i>					STATION <i>TS2</i>					134.7
STATION ANGLE	51 77 5		LOG CONV FT TO METERS	9.484 0158	LOG CONV FT TO METERS	9.484 0158	VERTICAL ANGLE	16 6	554 192.0	3 836 106.1	1.9				
Sum	80 38 8		LOG SCALE FACTOR		LOG SCALE FACTOR		LOG CONV FACTOR								
AS TO FWD STATION	16 38 8		LOG SIN BEARING	9.999 685	LOG COS BEARING	8.580 726	LOG TAN VERT ANGLE	8.212 147							
(+/-) 100'	32 00 0		DISTANCE	2.070 629	LOG DISTANCE	2.070 629	LOG DISTANCE	2.070 629							
AS TO REAR STATION	48 38 8		AS TO BEARING	117 66 7	STATION <i>TS3</i>					STATION <i>TS3</i>					132.8
STATION ANGLE	15 61 2		LOG CONV FT TO METERS	9.484 0158	LOG CONV FT TO METERS	9.484 0158	VERTICAL ANGLE		554 309.6	3 836 101.6					
Sum			LOG SCALE FACTOR		LOG SCALE FACTOR		LOG CONV FACTOR								
AS TO FWD STATION			LOG SIN BEARING		LOG COS BEARING		LOG TAN VERT ANGLE								
(+/-) 100'			DISTANCE		LOG DISTANCE		LOG DISTANCE								
AS TO REAR STATION			AS TO BEARING		STATION <i>TS3</i>					STATION <i>TS3</i>					
STATION ANGLE			LOG CONV FT TO METERS		LOG CONV FT TO METERS		VERTICAL ANGLE								
Sum			LOG SCALE FACTOR		LOG SCALE FACTOR		LOG CONV FACTOR								
AS TO FWD STATION			LOG SIN BEARING		LOG COS BEARING		LOG TAN VERT ANGLE								
(+/-) 100'			DISTANCE		LOG DISTANCE		LOG DISTANCE								

TO CONVERT AZIMUTH TO BEARING

BEARING = AZ - 100'

BEARING = AZ - 100'

LOG CONVERSION FACTORS

FEET TO METERS

FEET TO YARDS

YARDS TO FEET

STATION

COMPUTER

CHECKS

SHEET

OF

SHEETS

DA FORM 6-2 EDITION OF 1 OCT 62 IS OBSOLETE.

Figure 87. Sample computation of fifth-order traverse.

TABLE-UTM GRID SCALE FACTORS FOR ARTILLERY

Add log scale factor to log ground distance to obtain log UTM grid distance.
The easting value used to determine log UTM scale factor is easting of the known station to nearest 10,000 meters.

EASTING OF STARTING STATION		LOG SCALE FACTOR
500,000	500,000	9.9998300
490,000	510,000	9.9998300
480,000	520,000	9.9998300
470,000	530,000	9.9998300
460,000	540,000	9.9998300
450,000	550,000	9.9998400
440,000	560,000	9.9998400
430,000	570,000	9.9998500
420,000	580,000	9.9998600
410,000	590,000	9.9998700
400,000	600,000	9.9998800
390,000	610,000	9.9998900
380,000	620,000	9.9999000
370,000	630,000	9.9999200
360,000	640,000	9.9999300
350,000	650,000	9.9999500
340,000	660,000	9.9999700
330,000	670,000	9.9999800
320,000	680,000	0.0000000
310,000	690,000	0.0000200
300,000	700,000	0.0000400
290,000	710,000	0.0000600
280,000	720,000	0.0000900
270,000	730,000	0.0001100
260,000	740,000	0.0001300
250,000	750,000	0.0001600
240,000	760,000	0.0001900
230,000	770,000	0.0002200
220,000	780,000	0.0002500
210,000	790,000	0.0002800
200,000	800,000	0.0003100
190,000	810,000	0.0003400
180,000	820,000	0.0003700
170,000	830,000	0.0004100
160,000	840,000	0.0004500
150,000	850,000	0.0004800
140,000	860,000	0.0005200
130,000	870,000	0.0005600
120,000	880,000	0.0006000
110,000	890,000	0.0006400
100,000	900,000	0.0006900

Log Scale Factor

GIVEN:

Coordinates and Height of occupied station.
Azimuth STATION to REAR STATION.

FIELD DATA:

Observe horizontal angles and vertical angles.
Tape horizontal ground distance between occupied station and forward station.

GUIDE:

Enter field data in blocks marked. 
Sign of dH: (+) when elevation angle, (-) when depression angle.

LIMITATIONS:

This form should not be used for vertical control when horizontal distance exceeds 1,000 meters unless reciprocal vertical angles are observed and measured.

This computation requires that HI at occupied station and height of target at forward station be equal.

When distance exceeds 1,000 meters or when HI and height of target are unequal use DA Form 6-2b for more accurate vertical control.

RESULTS:

Coordinates and height of forward station.

FORMULA:

$dE = \text{dist.} \times \sin \text{Bearing}$ $dN = \text{dist.} \times \cos \text{Bearing}$ $dH = \text{dist.} \times \tan \text{vertical angle.}$

Figure 88. Back of DA Form 6-2.

AZIMUTH		STATION	DISTANCE AND BEARING TO FORWARD STATION		COMPUTATION - COORDINATES AND HEIGHT FROM AZIMUTH, DISTANCE AND VERTICAL ANGLE (FM 6-120)																
AZ TO REAR STATION					REAR STATION <i>Mike</i>					COORDINATES					HEIGHT						
STATION ANGLE			AZ TO READING		STATION <i>Joe</i>																
278 19 43										550 448.13					3 837 623.35	418.3					
+ 216 47 30			179 59 60		LOG COS PT TO BEARS	9.484 0158	LOG COS PT TO BEARS	9.484 0158	VERTICAL ANGLE	0 49 30	LOG TAN	0 49 30	LOG TAN	0 49 30	LOG TAN	0 49 30					
- 495 07 13			135 07 13		LOG SCALE FACTOR	9.999 8400	LOG SCALE FACTOR	9.999 8400	LOG COS FACTOR		LOG TAN	0 49 30	LOG TAN	0 49 30	LOG TAN	0 49 30					
360			44 52 50		LOG SIN BEARING	9.848 5777	LOG COS BEARING	9.850 3885	LOG TAN	8 158 3613	LOG TAN	8 158 3613	LOG TAN	8 158 3613	LOG TAN	8 158 3613					
AZ TO FWD STATION			DISTANCE		LOG DISTANCE	2.912 4293	LOG DISTANCE	2.912 4293	LOG DISTANCE	2.912 4293	LOG DISTANCE	2.912 4293	LOG DISTANCE	2.912 4293	LOG DISTANCE	2.912 4293					
(+/-) 180			817.39		LOG DISTANCE	2.912 4293	LOG DISTANCE	2.912 4293	LOG DISTANCE	2.912 4293	LOG DISTANCE	2.912 4293	LOG DISTANCE	2.912 4293	LOG DISTANCE	2.912 4293					
AZ TO REAR STATION					SUM A LOG	2.760 8470	SUM A LOG	2.762 6578	SUM P LOG	1.070 7906	SUM P LOG	1.070 7906	SUM P LOG	1.070 7906	SUM P LOG	1.070 7906					
+ STATION ANGLE			207 16 50		STATION <i>T 51</i>					551 024.69					3 837 044.38	406.5					
522 24 03			179 59 60		LOG COS PT TO BEARS	9.484 0158	LOG COS PT TO BEARS	9.484 0158	VERTICAL ANGLE	0 05 00	LOG TAN	0 05 00	LOG TAN	0 05 00	LOG TAN	0 05 00					
- 360			162 24 03		LOG SCALE FACTOR	9.999 8400	LOG SCALE FACTOR	9.999 8400	LOG COS FACTOR		LOG TAN	0 05 00	LOG TAN	0 05 00	LOG TAN	0 05 00					
AZ TO FWD STATION			17 36 00		LOG SIN BEARING	9.480 5385	LOG COS BEARING	9.979 1798	LOG TAN	7 162 6964	LOG TAN	7 162 6964	LOG TAN	7 162 6964	LOG TAN	7 162 6964					
(+/-) 180			943.57		LOG DISTANCE	2.974 7741	LOG DISTANCE	2.974 7741	LOG DISTANCE	2.974 7741	LOG DISTANCE	2.974 7741	LOG DISTANCE	2.974 7741	LOG DISTANCE	2.974 7741					
AZ TO REAR STATION					SUM A LOG	2.455 1526	SUM A LOG	2.953 7939	SUM P LOG	0.137 4705	SUM P LOG	0.137 4705	SUM P LOG	0.137 4705	SUM P LOG	0.137 4705					
+ STATION ANGLE			115 23 10		STATION <i>T 52</i>					551 309.89					3 836 145.31	405.1					
457 47 13			179 59 60		LOG COS PT TO BEARS	9.484 0158	LOG COS PT TO BEARS	9.484 0158	VERTICAL ANGLE	0 36 30	LOG TAN	0 36 30	LOG TAN	0 36 30	LOG TAN	0 36 30					
- 360			97 47 13		LOG SCALE FACTOR	9.999 8400	LOG SCALE FACTOR	9.999 8400	LOG COS FACTOR		LOG TAN	0 36 30	LOG TAN	0 36 30	LOG TAN	0 36 30					
AZ TO FWD STATION			82 12 50		LOG SIN BEARING	9.995 9775	LOG COS BEARING	9.131 8605	LOG TAN	8 026 0353	LOG TAN	8 026 0353	LOG TAN	8 026 0353	LOG TAN	8 026 0353					
(+/-) 180			1050.22		LOG DISTANCE	3.021 2803	LOG DISTANCE	3.021 2803	LOG DISTANCE	3.021 2803	LOG DISTANCE	3.021 2803	LOG DISTANCE	3.021 2803	LOG DISTANCE	3.021 2803					
AZ TO REAR STATION					SUM A LOG	3.017 0978	SUM A LOG	2.152 9808	SUM P LOG	1.047 3156	SUM P LOG	1.047 3156	SUM P LOG	1.047 3156	SUM P LOG	1.047 3156					
+ STATION ANGLE			233 45 45		STATION <i>Bn SCP</i>					552 350.04					3 836 003.08	416.3					
511 32 58			179 59 60		LOG COS PT TO BEARS	9.484 0158	LOG COS PT TO BEARS	9.484 0158	VERTICAL ANGLE	0 07 00	LOG TAN	0 07 00	LOG TAN	0 07 00	LOG TAN	0 07 00					
- 360			151 32 58		LOG SCALE FACTOR	9.999 8400	LOG SCALE FACTOR	9.999 8400	LOG COS FACTOR		LOG TAN	0 07 00	LOG TAN	0 07 00	LOG TAN	0 07 00					
AZ TO FWD STATION			28 27 00		LOG SIN BEARING	9.677 9642	LOG COS BEARING	9.944 1041	LOG TAN	7 308 8248	LOG TAN	7 308 8248	LOG TAN	7 308 8248	LOG TAN	7 308 8248					
(+/-) 180			1136.94		LOG DISTANCE	3.055 7376	LOG DISTANCE	3.055 7376	LOG DISTANCE	3.055 7376	LOG DISTANCE	3.055 7376	LOG DISTANCE	3.055 7376	LOG DISTANCE	3.055 7376					
AZ TO REAR STATION					SUM A LOG	2.733 5418	SUM A LOG	2.999 6817	SUM P LOG	0.364 5624	SUM P LOG	0.364 5624	SUM P LOG	0.364 5624	SUM P LOG	0.364 5624					
+ STATION ANGLE			331 32 58		STATION <i>T 53</i>					552 891.47					3 835 003.81	418.6					
TO CONVERT AZIMUTH TO BEARING					LOG CONVERSION FACTORS					STATION <i>T 53</i>					552 891.47					3 835 003.81	418.6
BEARING S AC - 180					LOG CONVERSION FACTORS					STATION <i>T 53</i>					552 891.47					3 835 003.81	418.6
BEARING S AC - 180					LOG CONVERSION FACTORS					STATION <i>T 53</i>					552 891.47					3 835 003.81	418.6

DA FORM 6-2 EDITION OF 1 OCT 52 IS OBSOLETE.

Figure 89. Sample computation of fourth-order traverse.

COMPUTATION—TRIGONOMETRIC HEIGHTS										
OCCUPIED STATION			SCP 2		SCP 3					
FORWARD STATION			SCP 3		SCP 4					
HORIZONTAL DISTANCE BETWEEN STATIONS										
			GROUND ☐		UTM GRID ☐					
BLOCK I	1	HEIGHT OF INSTRUMENT AT OCCUPIED STATION	+	1.6	+	1.6	+			
	2	HEIGHT OF TARGET AT FORWARD STATION	-	1.6	-	1.6	-			
	3	ALGEBRAIC SUM (1) AND (2)	+	0.0	+	0.0	+			
BLOCK II RECIPROCAL ANGLES ONLY	4	HEIGHT OF INSTRUMENT AT FORWARD STATION	-	1.6	-	1.6	-			
	5	ALGEBRAIC SUM (3) AND (4)	+	1.6	+	1.6	+			
	6	HEIGHT OF TARGET AT OCCUPIED STATION	+	1.6	+	1.6	+			
	7	ALGEBRAIC SUM (5) AND (6)	+	0.0	+	0.0	+			
	8	1/2 OF (7)	+	0.0	+	0.0	+			
	9	VERTICAL ANGLE OCCUPIED STATION TO FORWARD STATION	+	1 03 46	+	0 34 45	+			
	10	VERTICAL ANGLE FORWARD STATION TO OCCUPIED STATION WITH SIGN REVERSED	+	1 03 52	+	0 34 53	+			
	11	ALGEBRAIC SUM (9) AND (10)	+	2 07 38	+	1 09 38	+			
	12	1/2 OF (11)	+	1 03 49	+	0 34 49	+			
	BLOCK III NON-RECIPROCAL ANGLES ONLY									
	12	VERTICAL ANGLE OCCUPIED STATION TO FORWARD STATION	+		+		+		+	
	BLOCK IV	13	LOG OF HORIZONTAL DISTANCE BETWEEN STATIONS		3.939 2108		3.534 8363			
14		LOG TAN (12)		8.268 7101		8.005 5282				
15		(13) + (14)		2.207 9209		1.540 3645				
16		IF HORIZONTAL DISTANCE IS: GRID, USE LOG SCALE FACTOR FROM REVERSE; GROUND, LEAVE BLANK		9.999 8400		9.999 8400				
17		(15) - (16)		2.208 0809		1.540 5245				
18		NUMBER HAVING LOG (17) USE SIGN OF (12)	+	161.5	+	34.7	+			
19		IF BLOCK II IS BLANK REPEAT (3) IF BLOCK II IS FILLED REPEAT (8)	+	0.0	+	0.0	+			
20		ALGEBRAIC SUM (18) AND (19)	+	161.5	+	34.7	+			
21		NON-RECIPROCAL ANGLES ONLY: CURVATURE AND REFRACTION CORRECTION FROM REVERSE	+		+		+			
22		ALGEBRAIC SUM (20) AND (21)	+	161.5	+	34.7	+			
23		HEIGHT OF ☐ OCCUPIED ☐ FORWARD STATION	+	371.6	+	533.1	+			
24		IF (23) IS HEIGHT OF OCCUPIED STATION REPEAT (22); IF (23) IS HEIGHT OF FORWARD STATION REPEAT (22) WITH OPPOSITE SIGN	+	161.5	+	34.7	+			
25		ALGEBRAIC SUM (23) AND (24) = HEIGHT OF ☐ OCCUPIED ☐ FORWARD STATION		553.1		498.4				
COMPUTER			Cpl Jones				CHECKER		Cpl Smith	
NOTEBOOK REFERENCE			1-16-58		AREA		Fox trot		DATE	
									16 Jan 58	
DA FORM 6-2b			REPLACES DA FORM 6-2b, 1 OCT 52, WHICH IS OBSOLETE.							

Figure 90. Computation of heights, fourth-order survey.

TABLE - CORRECTION FOR CURVATURE AND REFRACTION
(No interpolation necessary for Artillery Survey)
Use only when dH is computed using non-reciprocal vertical angles.
SIGN ALWAYS PLUS
Enter in (21)

Log Dist (M)	Corr (M)
3,079	.1
3,230	.2
3,322	.3
3,386	.4
3,435	.5
3,473	.6
3,508	.7
3,537	.8
3,562	.9
3,584	1.0
3,625	1.2
3,658	1.4
3,887	1.6
3,712	1.8
3,736	2.0
3,784	2.5
3,824	3.0
3,857	3.5
3,886	4.0
3,912	4.5
3,934	5.0
3,955	5.5
3,974	6.0
3,992	6.5
4,007	7.0

TABLE - UTM GRID SCALE FACTORS FOR ARTILLERY
EASTING OF STARTING STATION LOG SCALE FACTOR

500,000	500,000	9,9998300
490,000	510,000	9,9998300
480,000	520,000	8,9998300
470,000	530,000	9,9998300
460,000	540,000	9,9998300
450,000	550,000	9,9998400
440,000	560,000	9,9998400
430,000	570,000	9,9998500
420,000	580,000	9,9998600
410,000	590,000	8,9998700
400,000	600,000	9,9998900
390,000	610,000	9,9998900
380,000	620,000	9,9999000
370,000	630,000	9,9999200
360,000	640,000	9,9999300
350,000	650,000	9,9999500
340,000	660,000	8,9999700
330,000	670,000	0,9999800
320,000	680,000	0,0000000
310,000	690,000	0,0000200
300,000	700,000	0,0000400
290,000	710,000	0,0000600
280,000	720,000	0,0000900
270,000	730,000	0,0001100
260,000	740,000	0,0001300
250,000	750,000	0,0001600
240,000	760,000	0,0001900
230,000	770,000	0,0002200
220,000	780,000	0,0002500
210,000	790,000	0,0002800
200,000	800,000	0,0003100
190,000	810,000	0,0003400
180,000	820,000	0,0003700
170,000	830,000	0,0004100
160,000	840,000	0,0004500
150,000	850,000	0,0004800
140,000	860,000	0,0005200
130,000	870,000	0,0005900
120,000	880,000	0,0006000
110,000	890,000	0,0006400
100,000	900,000	0,0006900

Given:

UTM grid distance or horizontal ground distance in meters between stations.
Height of one station in meters.

Field data:

Observe vertical angle between instrument at one station and target at other station.
Height of instrument.
Height of target.

Guide:

Enter field data in blocks marked **1**.

When vertical angles are observed in two directions, either station may be designated as the occupied station. Use Blocks I, II, and IV.

When vertical angle is observed in one direction, use Blocks I, III, and IV. Use curvature and refraction correction from table above.

Elevation of occupied station need not be known.

In (16), obtain approximate easting coordinate of occupied station from other computations or from map. Use this value to obtain scale factor from table above.

If height of either station in (23) is below sea level (-), add 1,000 meters algebraically to (23); proceed with computation as indicated. Subtract 1,000 meters algebraically from (25) to obtain height of station.

If height of occupied station is used in (23), then height of forward station is obtained in (25).

All angular units used in computation must be the same (mils or degrees).

Limitation:

This computation does not provide for reduction of ground distance to sea level distance.

Results:

Height of the unknown station in meters.

Figure 91. Back of DA Form 6-2b.

COMPUTATION - AZIMUTH AND DISTANCE FROM COORDINATES (FM 6-120)												
STATION		E COORDINATE			N COORDINATE			AZ. = 360° - Bearing dE - dN +				
FROM	Pet	A	554	187	61	A	3	835	928	41		
TO	Dog	B	553	864	21	B	3	836	080	39		
IF A IS LESS THAN B, REPEAT A		AA				AA						
IF AA IS BLANK, USE A - B, SIGN (-) IF AA IS FILLED, USE B - AA, SIGN (+)		dE	+	323	40	dN	+	151	98			
LOG dE		2			509	740	ANGLE HAVING LOG TAN BEARING A TO B		11	52	5	
LOG dN		2			181	786	DETERMINE AZIMUTH FROM BEARING BY PLOTTING dE AND dN ON SKETCH AND USING SKETCH AS GUIDE		64	00	0	
LOG dE - LOG dN = LOG TAN BEARING A TO B		0			327	954	AZIMUTH A TO B		11	52	5	
								52		47	5	
IF dE IS MORE THAN dN					IF dE IS LESS THAN dN							
REPEAT LOG dE		2			509	740	REPEAT LOG dN					
LOG SIN BEARING		9			956	666	LOG COS BEARING					
LOG dE - LOG SIN BEARING = LOG GRID DISTANCE A TO B IN METERS		2			553	074	LOG dN - LOG COS BEARING = LOG GRID DISTANCE A TO B IN METERS					
LOG CONVERSION FACTOR METERS TO YARDS		0			038	8629	LOG CONVERSION FACTOR METERS TO YARDS		0			
LOG GRID DIST IN M. + LOG CONV FACTOR = LOG GRID DISTANCE A TO B IN YARDS								LOG GRID DIST IN M. + LOG CONV FACTOR = LOG GRID DISTANCE A TO B IN YARDS				
		357			3	0			M			
										YDS		
STATION		E COORDINATE			N COORDINATE			AZ. = 360° - Bearing dE - dN +				
FROM		A				A						
TO		B				B						
IF A IS LESS THAN B, REPEAT A		AA				AA						
IF AA IS BLANK, USE A - B, SIGN (-) IF AA IS FILLED, USE B - AA, SIGN (+)		dE	+			dN	+					
LOG dE					ANGLE HAVING LOG TAN BEARING A TO B							
LOG dN					DETERMINE AZIMUTH FROM BEARING BY PLOTTING dE AND dN ON SKETCH AND USING SKETCH AS GUIDE							
LOG dE - LOG dN = LOG TAN BEARING A TO B					AZIMUTH A TO B							
IF dE IS MORE THAN dN					IF dE IS LESS THAN dN							
REPEAT LOG dE					REPEAT LOG dN							
LOG SIN BEARING					LOG COS BEARING							
LOG dE - LOG SIN BEARING = LOG GRID DISTANCE A TO B IN METERS					LOG dN - LOG COS BEARING = LOG GRID DISTANCE A TO B IN METERS							
LOG CONVERSION FACTOR METERS TO YARDS		0			038	8629	LOG CONVERSION FACTOR METERS TO YARDS		0			
LOG GRID DIST IN M. + LOG CONV FACTOR = LOG GRID DISTANCE A TO B IN YARDS					LOG GRID DIST IN M. + LOG CONV FACTOR = LOG GRID DISTANCE A TO B IN YARDS							
					M							
					YDS							
FORMULAS:												
TAN BEARING = $\frac{dE}{dN}$		GRID DISTANCE = $\frac{dE}{\sin \text{BEARING}}$		=		COS BEARING						
COMPUTER		CHECKER		SHEET		OF		SHEETS				
NOTEBOOK REFERENCE		AREA		DATE								

DA FORM 6-1 REPLACES EDITION OF 1 NOV 55, WHICH WILL BE USED UNTIL EXHAUSTED.

Figure 92. Computation of azimuth and distance, fifth-order survey.

necessary. The standardized form for this computation is DA Form 6-1 (fig. 92).

226. DA Form 6-1

a. DA Form 6-1 (fig. 92) is used to determine the azimuth and distance between two points of known coordinates.

b. Entries on the form are the coordinates of the two known points.

c. Formulas to be used are shown on the front of DA Form 6-1.

227. Accuracy Ratio

a. To determine whether the minimum accuracy requirements for a closed traverse have been met, an accuracy ratio is computed. If computation of the accuracy ratio reveals that the minimum prescribed accuracy for the traverse has not been met and the errors cannot be determined, the traverse must be rerun. An accuracy ratio is determined as a ratio between the radial error of closure and the total length of the traverse. This ratio is expressed as a fraction with a numerator of 1 (e.g., 1:1,000 (1/1000), 1:3,000 (1/3000)). The radial error of closure is the linear distance between the correct coordinates of the closing station and the coordinates of that station as determined from the traverse. The equation for the determination of accuracy ratio is as follows:

$$\text{Accuracy ratio} = \frac{1}{\text{total length of traverse} \div \text{radial error}}$$

After computation of the accuracy ratio, the denominator of the fraction is always reduced to the next lower hundred (e.g., 1:1,099 becomes 1:1,000). To determine the radial error of closure, the correct coordinates of the closing point are compared with the traverse coordinates of that point and the difference is determined,

Correct coordinates

of closing point: 560068.0-3838037.0

Traverse coordinates

of closing point: 560064.0-3838040.0

$eE = 4.0$ $eN = 3.0$

The difference between the two eastings of the closing point, error in easting (eE), forms one side of the right triangle in figure 93; the difference between the two northings, error in northing (eN), forms a second side. The hypotenuse of the right triangle is the radial error of closure.

b. The radial error may be determined by computation on DA Form 61, by the Pythagorean theorem, or by plotting eE and eN to scale and measuring the hypotenuse. The most common of these systems used is the Pythagorean theorem, which, by using data in figure 93, would be computed as follows:

$$\begin{aligned} \text{Radial error: } & \sqrt{(eE)^2 + (eN)^2} \\ & : \sqrt{4.0^2 + 3.0^2} \\ & : \sqrt{16.0 + 9.0} \\ & : \sqrt{25.0} \\ & : 5.0 \text{ meters} \end{aligned}$$

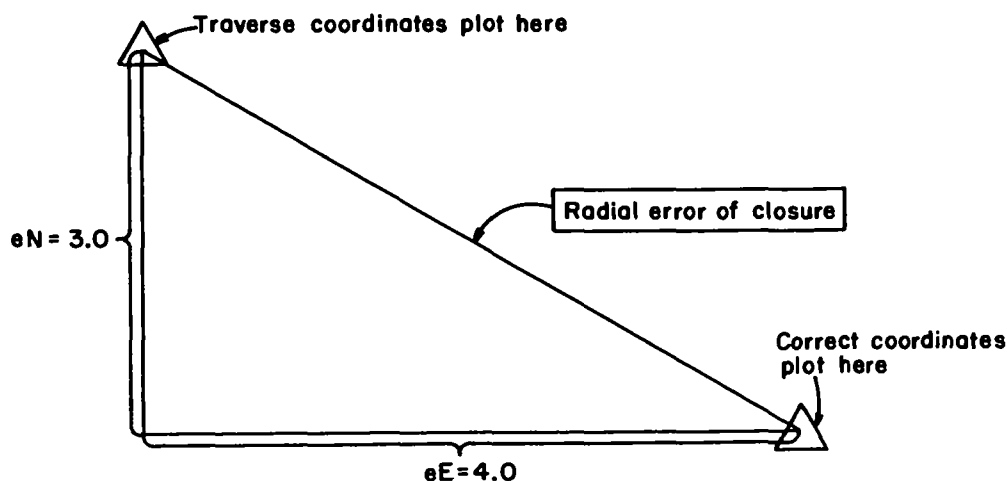


Figure 93. Schematic diagram showing radial error of closure.

When the radial error of closure has been determined, one other factor is required to complete the computation of the accuracy ratio. This factor is the total length of the traverse which is determined by adding the distances of all traverse legs (excluding distances to offset stations) in the traverse. Assuming that for the radial error computed above the total length of the traverse is 5,555 meters, the accuracy would be determined as follows:

Accuracy ratio:

$$\frac{1}{\text{total length of traverse} \div \text{radial error}}$$

$$: \frac{1}{5555 \div 5.0}$$

$$: \frac{1}{1111} \text{ or, rounded down}$$

$$: \frac{1}{1100}$$

228. Closing Azimuth Error

The closing azimuth error is determined by comparing the known closing azimuth with the closing azimuth determined by the traverse. The difference between the two is the closing azimuth error. The error is considered within tolerances if it does not exceed 0.5 mil per station angle for a 1:500 traverse, 0.1 mil per station angle for a fifth-order traverse, and 5 seconds per station angle for a fourth-order traverse.

Section III. TRAVERSE ADJUSTMENT

229. General

Establishing a common grid throughout an entire corps or division artillery sector is not as simple as it may at first appear. When extending survey control over long distances by traverse, a traverse party may well be within the prescribed accuracy and still be considerably in error. This problem is magnified when several traverse parties are employed to extend control and attempt to tie their work together. Seldom, if ever, will these parties coincide on their linkage, but, by adjusting the traverse throughout, some compensation will be made for those errors which have accumulated. Traverses executed to a prescribed accuracy of fourth-order must always be closed and adjusted. An adjusted traverse is one in which the errors have been distributed systematically so that the closing data as determined by the traverse coincides with the correct closing data. There is, of course, no possible means of determining the true magnitude of the errors in angle and distance measuring which occur throughout a traverse. Traverse adjustment is based on the assumption that the errors have gradually accumulated, and the corrections are made accordingly. There are three adjustments that must be made in adjusting a traverse—azimuth, coordinates, and height. These adjustments eliminate the effects of systematic errors on the assumption that they have been

constant and equal in their effect upon each traverse leg. Blunders, such as dropped tape lengths or misreading of angles, cannot be compensated for in traverse adjustment. Additionally, traverses which do not meet the prescribed standard of accuracy are not adjusted but are checked for error. *If the error cannot be found, the traverse must be performed again from the start.*

230. Sources of Errors

The sources of errors that are compensated for by traverse adjustment are not those errors commonly known as mistakes or blunders but are errors that fall into one of the following classes:

a. Instrumental errors—Errors that arise from imperfections in, or faulty adjustment of, the instruments with which the measurements are taken. For example, a tape may be too long or too short or a plate level may be out of adjustment.

b. Personnel errors—Errors that arise from the limitations of the human senses of sight and touch. For example, an error may be made in estimating the tension applied to a steel tape.

c. Natural errors—Errors that arise from variations in the phenomena of nature, such as temperature, humidity, wind, gravity, refraction, and magnetic declination. For example, the length of tape will vary directly with the

temperature; i.e., it will become longer as the temperature increases and shorter as the temperature decreases.

231. Azimuth Adjustment

a. Determining Azimuth Correction. Since the computation of position is in part dependent on azimuth, the first step in adjusting a traverse is to determine the azimuth error and correct it. The azimuth error is obtained by determining the difference between the azimuth established by traverse (computed) and the correct azimuth. The azimuth correction is the azimuth error with a sign affixed which will cause the computed azimuth, with the correction applied, to equal the correct azimuth. For example, the correct azimuth from a point to an azimuth mark is known to be $137^{\circ} 47' 11''$. The closing azimuth of a traverse to the same azimuth mark is determined to be $137^{\circ} 46' 52''$. To determine the azimuth correction, the following computations are performed:

$$\begin{aligned}\text{Azimuth error} &= \text{correct azimuth} - \text{azimuth established by traverse.} \\ &= 137^{\circ} 47' 11'' - 137^{\circ} 46' 52'' \\ &= 19''\end{aligned}$$

$$\text{Azimuth correction} = +19''$$

b. Application of Azimuth Correction. Since traverse adjustment is based on the assumption that errors present have accumulated gradually and systematically throughout the traverse, the azimuth correction is applied accordingly. The correction is distributed equally among the angles of the traverse with any remainder distributed to the larger angles. For example, assume that the traverse, for which the azimuth correction was determined, consisted of three traverse legs and four angles as follows:

Traverse leg	Measured angle
SCP-TS 1	$135^{\circ} 36' 10''$ (Az Mk-SCP-TS 1)
TS 1-TS 2	$155^{\circ} 13' 45''$ (SCP-TS 1-TS 2)
TS 2-SCP	$211^{\circ} 49' 50''$ (TS 1-TS 2-SCP)
SCP (Closing)	$37^{\circ} 19' 56''$ (TS 2-SCP-Az Mk)

To distribute the azimuth correction throughout the traverse, divide it by the total number of angles. In this case, $+19'' \div 4 = +4''$ per angle with a remainder of $3''$. Each of the four angles will be adjusted by $4''$ with the three largest angles receiving an additional 1 second each to compensate for the remaining 3 seconds.

Station	Measured angle	Azimuth correction	Adjusted angle
SCP	$135^{\circ} 36' 10''$	$+05''$	$135^{\circ} 36' 15''$
TS 1	$155^{\circ} 13' 45''$	$+05''$	$155^{\circ} 13' 50''$
TS 2	$211^{\circ} 49' 50''$	$+05''$	$211^{\circ} 49' 55''$
SCP	$37^{\circ} 19' 56''$	$+04''$	$37^{\circ} 20' 00''$

c. Action After Adjustment. After the angles have been adjusted, the adjusted azimuth for each leg of the traverse should be computed by using the starting azimuth and the adjusted angles at each traverse station. These computations should be performed on fresh sheets of DA Form 6-2, not on the sheets used in the original computations. The adjusted azimuth should be computed throughout the entire traverse and checked against the correct azimuth to the closing azimuth mark before any of the coordinate adjustments are begun.

232. Coordinate Adjustment

After the azimuth of each traverse leg has been adjusted, the coordinates of the stations in the traverse must be adjusted. The first step in adjusting the coordinates is to recompute the coordinates of all stations in the traverse, using the adjusted azimuths to obtain new bearing angles.

a. Determining Easting and Northing Corrections. The easting and northing correction for the traverse is determined by subtracting the coordinates of the closing station (as recomputed with the adjusted azimuth) from the correct coordinates of the closing station.

Example:

$$\begin{aligned}\text{Correction} &= \text{correct coordinates} - \text{coordinates established by traverse} \\ &= 550554.50 - 3835829.35 \text{ (correct coordinates)} \\ &= 550550.50 - 3835835.35 \text{ (traverse coordinates)} \\ &= +4.00 \quad -6.00\end{aligned}$$

b. Application of Easting and Northing Corrections. The corrections determined in *a* above are for the entire traverse. The assumption is made that these corrections are based on errors proportionately accumulated throughout the traverse. To apply the correction, it must be distributed proportionately. The amount of easting or northing correction to be applied to the coordinates of each station is computed by multiplying the total correction

(easting or northing) by the total length of all the traverse legs up to that station and dividing it by the total length of all of the legs in the traverse. For example, using the total easting and northing corrections previously determined, assume that the total length of the traverse was 22,216.89 meters and that the total length of the traverse legs up to TS 4 was 3,846.35 meters.

Easting correction at—

$$\begin{aligned}\text{TS 4} &= \frac{\text{Total easting correction} \times \text{traverse length to TS 4}}{\text{total traverse length}} \\ &= \frac{+ 4.00 \times 3,846.35}{22,216.89} \\ &= \frac{+ 15,385.40}{22,216.89} \\ &= + 0.69 \text{ meter}\end{aligned}$$

Northing Correction at—

$$\begin{aligned}\text{TS 4} &= \frac{\text{Total northing correction} \times \text{traverse length to TS 4}}{\text{total traverse length}} \\ &= \frac{- 6.00 \times 3,846.35}{22,216.89} \\ &= \frac{- 22,478.10}{22,216.89} \\ &= - 1.04 \text{ meters}\end{aligned}$$

233. Height Adjustment

Like azimuth adjustment, the height adjustment is based on the assumption that the error of closure is accumulated throughout the traverse in equal amounts at each traverse station.

a. Determining Height Correction. The

height correction is determined by comparing the height of the closing point as established by the traverse with the known correct height of the closing point and applying a sign which will cause the established height, with the correction applied algebraically, to equal the correct height.

Example:

$$\begin{aligned}\text{Height correction:} &= \text{correct height} - \text{height established by traverse} \\ &= 478.3 \text{ meters} - 477.5 \text{ meters} \\ &= + 0.8 \text{ meter}\end{aligned}$$

b. Application of Height Correction. The height correction is distributed evenly throughout all stations of the traverse with any remainder distributed to those stations for which the greatest dH was determined. The height correction is not applied to the traverse height

of each station but is applied to the difference in height (dH) between each traverse station.

Station	Traverse height	dH	Correction	Adjusted height
SCP	478.3			478.3
TS 1	486.7	+ 8.4	+ 0.2	486.9
TS 2	495.9	+ 9.2	+ 0.3	496.4
SCP	477.5	- 18.4	+ 0.3	478.3

Section IV. LOCATION OF TRAVERSE ERRORS

234. Analysis of Traverse for Errors

A good survey plan when executed by a well-trained party provides for numerous checks in both computations and fieldwork. However, these checks do not always eliminate errors. On the contrary, errors are made both in the fieldwork and in computations and are often not discovered until the survey has been completed. The surveyor should be able to isolate these errors and determine their causes. Often an analysis of the fieldwork and the computations of a survey in error will save hours of repetitious labor and computations. To assist in this analysis, the chief of survey party should maintain in the field a sketch, to scale, of each survey as it is being performed. If available, a reliable map can also be used to advantage. Upon completion of the survey, if an error is apparent, the following considerations will be made. To isolate an error in a traverse, an assumption must be made that only one error exists. If more than one error exists, then it will not be possible to isolate the errors.

235. Isolation of Distance Error

a. Indication of Distance Error. The azimuth for the traverse will close within the allowable tolerance; however, the coordinate closure will be in error beyond the limits allowed for the prescribed accuracy.

b. Isolation of Distance Error. Compare the known coordinates of the closing point to the computed coordinates of that point. From this comparison, determine the error in easting and

the error in northing. Compute the distance (radial error) and azimuth from the known coordinates to the computed coordinates. If a distance error had been made, the traverse leg containing the distance error will have the same azimuth (or back-azimuth) as the radial error (fig. 94), and the distance error will be approximately the same length as the radial error. The suspected traverse leg is then re-measured to verify the isolation of the error. Under some circumstances, several legs with azimuths approximating the azimuth of the radial error may be suspected as containing the error. In this case, check the computations for each suspected leg. If there is no error in the computations, then each suspected leg must be re-measured until that leg containing the error is found.

236. Isolation of Azimuth Error

a. Indication of Azimuth Error. The azimuth closure and the coordinate closure will be in error beyond the limits allowed for the prescribed accuracy.

b. Isolation of Azimuth Error. Compare the computed azimuth to the known azimuth of the closing point, and determine the azimuth error. Determine the azimuth and distance of the radial error. Construct a scaled sketch of the traverse. Draw in the radial error, and then construct a line perpendicular to and at the midpoint of the radial error. Extend this line through the area in the sketch showing the fieldwork. The station at which the angular error was made will be on or very near this

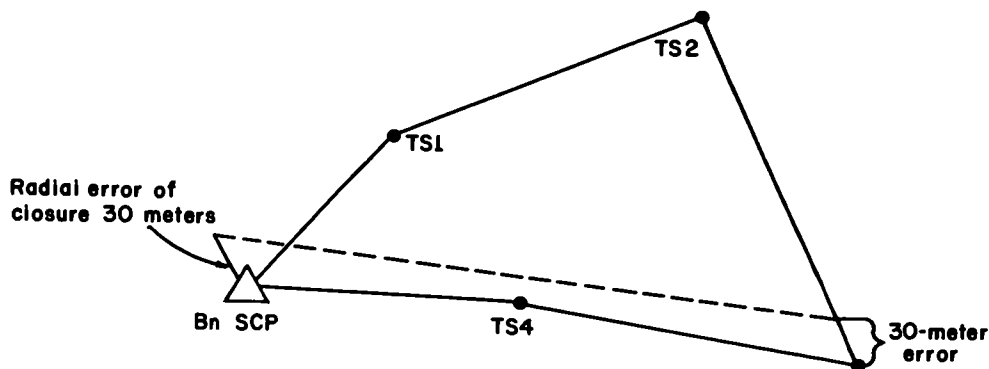


Figure 94. Distance error.

extended line. Check the computations and the field notes for that station. If no error can be found, remeasure the angle. If the remeasured angle compares favorably with the original angle, then a multiple error exists and the survey must be rerun.

c. Alternate Solution. Another procedure which can be used when a graphical plot cannot be made is to determine the approximate distance of the station in error from the closing station. This is determined by using the mil relation formula ($m = w \div r$), the distance of the radial error, and the azimuth error of closure. The radial error is substituted for the width, and the azimuth error of closure is substituted for the mills in the formula.

Example:

Range (in thousands) to suspected station =
radial error $\div$ azimuth errors of closure.

$$\begin{aligned} r &= w \div m \\ &= 100 \text{ meters} \div 10 \text{ mils} \\ &= 10 \text{ (range in thousands)} \\ &= 10,000 \text{ meters} \end{aligned}$$

By using this procedure, one or more suspect stations may be determined; and then by trial and error procedure and systematic elimination the suspected station in error may be located. This is done by using the known coordinates of the closing station and the coordinates of the suspected station and computing the azimuth and distance between the two. The computed coordinates of the closing station and the coordinates of the suspected station are used to compute the azimuth and distance between the two. If the error is at that station, the azimuths should vary by the amount of the error of the azimuth closure of the traverse, and the distances will be approximately the same. If the error is not at that station, the azimuths will disagree but not by an amount equivalent to the azimuth closure error (fig. 95). This procedure is repeated for each of the suspected stations. When the suspected station has been isolated, check the computations and field notes for that station. If no error can be found, remeasure the angle at the station. If the remeasured angle compares favorably to the original angle, rerun the entire survey.

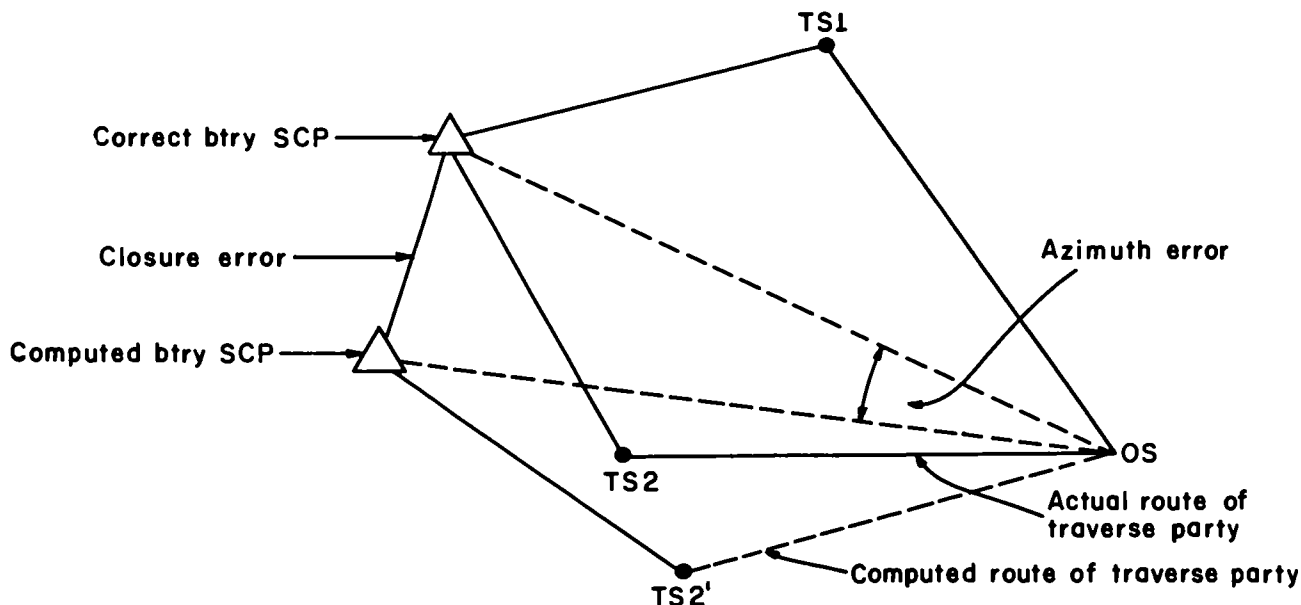


Figure 95. Azimuth error.

CHAPTER 15

TRIANGULATION

Section I. GENERAL

237. General

a. Triangulation is a method of survey which employs triangular figures to obtain survey data. If the values of certain elements of a triangle are known, the values of other elements of the triangle can be computed; e.g., if the length of one side and two angles of a triangle are known, the size of the third angle and the other two sides can be computed. *In the artillery the term "triangulation" is restricted to mean operations which involve the measurement of all three of the angles of a triangle.* If only two angles and a side are measured, the method is known as *intersection*. If only the three sides are measured, the method is known as *trilateration*. Another method is *resection*, in which the coordinates of a point are determined by measuring the

angles between two or three unoccupied points of known coordinates.

b. Triangulation involves single triangles (fig. 96) as well as chains or schemes of triangles (fig. 97). In a chain of triangles, the unknown elements are progressively solved by using data determined by computation from the preceding triangle.

238. Specifications and Techniques

In triangulation, certain specifications and techniques are adhered to in both fieldwork and computations to produce an end product of the desired accuracy. These specifications and techniques are shown in appendix II.

239. Triangulation Field Notes

Examples of triangulation field notes are shown in figures 71 through 74.

GENERAL

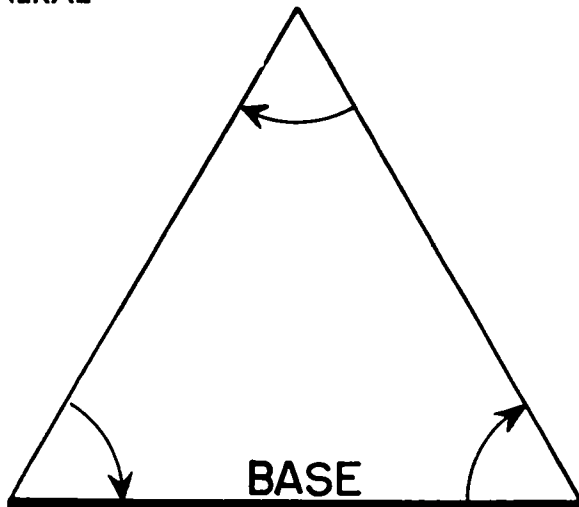
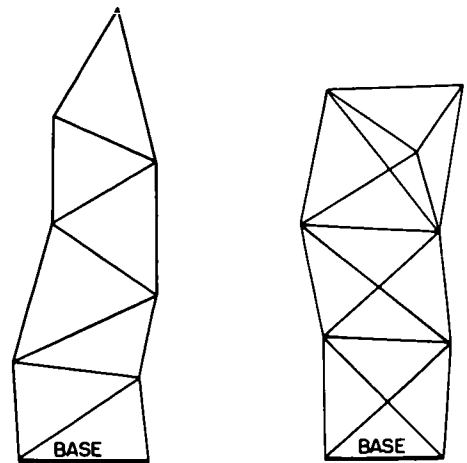


Figure 96. Single triangle.



CHAIN OF SINGLE TRIANGLES CHAIN OF QUADRILATERALS

Figure 97. Triangulation schemes.

Section II. SINGLE TRIANGLE AND SINGLE CHAIN

240. Description and Solution of the Single Triangle

A triangle is defined as a three-sided figure, the sum of whose interior angles equals 180° (3,200 mils). If the length of one side and the value of all three interior angles are known, the length of either unknown side may be found by the law of sines, or a is to $\sin A$ as b is to $\sin B$ as c is to $\sin C$ (fig. 98). This then becomes a proportion-type problem.

a. To determine the length of side b —

$$b : \sin B :: a : \sin A$$

$$\frac{b}{\sin B} = \frac{a}{\sin A}$$

$$b = \frac{a \times \sin B}{\sin A}$$

b. To determine the length of side c —

$$c : \sin C :: a : \sin A$$

$$\frac{c}{\sin C} = \frac{a}{\sin A}$$

$$c = \frac{a \times \sin C}{\sin A}$$

241. Survey Application of Basic Triangle

To determine the coordinates of a point from a point of known coordinates, three items of information are needed—a vertical angle, an azi-

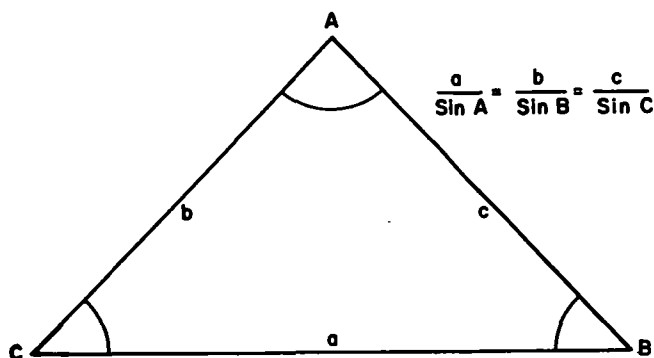


Figure 98. Schematic drawing showing law of sines.

imuth, and a distance. These items become the objectives of any work in the field regardless of the method of survey employed. To associate the basic triangle in figure 99 with these objectives, assume that point A on this triangle is a point on the ground the coordinates and height of which are to be determined by triangulation. In order to accomplish this, the following steps must be taken:

a. Select two other points, B and C, inter-visible to each other and point A. The coordinates and height of at least one of these two points must be known.

b. Measure the interior angles and vertical angles at all three points with an instrument. At the same time, establish the azimuth of one of the sides.

c. The last item needed is the length of one of the sides of the triangle. If the coordinates and height of both B and C are known, the distance between them can be computed on a DA Form 6-1; if not known the distance must be measured.

d. The triangle can now be solved for either the length AB (side c) or length AC (side b). In solving for one of these sides, the coordinates and height of point A can then be determined. The decision as to which side to compute will be based on distance angles.

242. Distance Angles of a Single Triangle

Distance angles are defined as those angles in a triangle opposite the known side and the required side (side common to an adjacent triangle). Since in a single triangle there is no required side, the distance angles in a single triangle are the angles opposite the known side and the stronger (closest to 90° or 1,600 mils) of the remaining two angles. In a single triangle, the side which is computed is the side opposite the strongest angle at the base. For example, in figure 99, it is apparent that all of the elements needed are present to determine the length of either side AC or AB. In this triangle, the distance angles are at A (angle opposite the known side) and at C (angle closest to 90° of the remaining two angles). The side the length of which should be determined is side AB. If the coordinates and height

of point B were known, the coordinates and height of point A would be determined, as in traverse by using the azimuth and distance of side BA and the vertical angle measured at B to A. If the coordinates of point B were not known and the coordinates of point C were known, the coordinates and height of point A would be determined, again as in traverse, but by going from C to B and then to A.

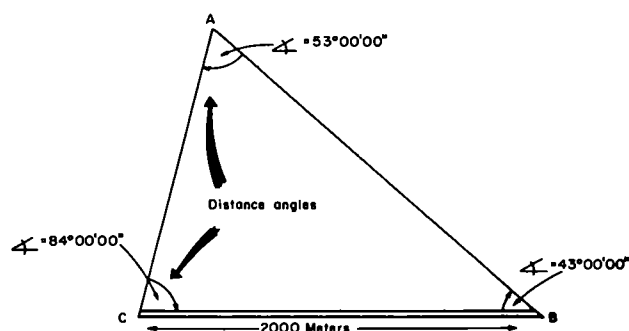


Figure 99. Schematic drawing showing distance angles of a single triangle.

243. Description and Solution of a Single Chain of Triangles

A single chain of triangles is a scheme of single triangles connected by common sides. In figure 100 side AB is common to triangles ABC and ABD. Each of these triangles may be individually solved by using the law of sines, if one side and the interior angles are known.

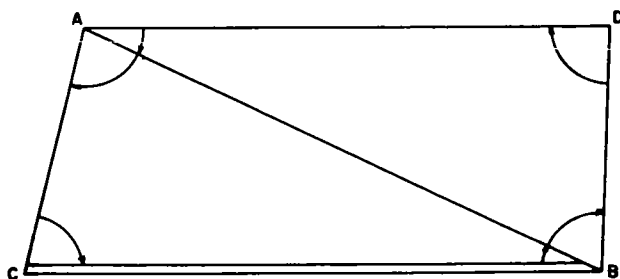


Figure 100. Schematic drawing showing a single chain of triangles.

244. Survey Application of the Single Chain of Triangles

In figure 100, assume that it is required to locate an additional point, D, outside the single triangle ABC. While the interior and vertical angles at A and B were being measured, the angles for the new triangle would also be taken.

Then the angles at point D would be measured. All the information necessary to compute both triangles would then be available. Note that side AB is common to both triangles. In solving for triangle ABC, side AB would be the required side and angle C would be its distance angle, regardless of its value.

245. Distance Angles of a Single Chain of Triangles

As stated in paragraph 242, a distance angle is an angle in a triangle opposite the known side or opposite the required side (side common to an adjacent triangle). The required side is also known as the forward line or forward base, in that it will become the base for the next triangle in the scheme. In a chain of single triangles, the last triangle in the scheme will be handled as a single triangle, and its distance angles will be determined as discussed in paragraph 242. For example, in figure 100 the distance angles in triangle ABC are at points A (angle opposite known side CB) and C (angle opposite required side AB), whereas in triangle ABD, the distance angles are at points D (side opposite known side AB which had been solved in triangle ABC) and B (the stronger of angles A and B).

246. Strength of Angles

The results obtained by triangulation in the field will depend in part on the strength of the triangular figures established. In reconnoitering for a triangulation scheme, one of the points which the surveyor must keep in mind is the strength of angles in the triangles which he established. A strong angle is one which approaches a right angle, or 90° (1,600 mils). As the law of sines will be used to solve the triangulation problem, a small error in the value of an angle near 0° will cause a relatively large error in the sine of that angle and a corresponding error in the computed length of the side opposite that angle. For this reason, distance angles must be between $22\frac{1}{2}^\circ$ and $157\frac{1}{2}^\circ$ (400 mils and 2,667 mils). It is for this reason that, in a single triangle, the side opposite the stronger angle is the side computed.

247. Triangle Closure

Triangle closure is another term for adjustment of the angles within a triangle. For a figure to be a triangle, it must have three sides

STATION	OBSERVED ANGLES	CORRECTION	CORRECTED ANGLES
A	133 00	+ 1	133 01
B	978 90	+ 0	978 90
C	888 00	+ 0	888 00
SUM OF ANGLES	3199 90		3200 00

TO FIND STATION ANGLE AT C

159° 59' 60"

OR 160 00

- CORRECTED $\angle$ C

888 00

STATION ANGLE AT C

55 12 00

DE- $\angle$ C

DE- $\angle$ C

DE- $\angle$ C

DE- $\angle$ C

360°

6400 M

840 08

3200 M

40 40 8

40 40 8

LOG SIN

3 004 511

LOG COS

9 866 202

SUM = LOG DE

2 870 713

LOG SIDE REPEAT(S)

3 004 511

LOG COS BEARING

9 836 419

SUM = LOG GH

1 404 843

6 VERT $\angle$ STA $\rightarrow$ FWD STA

25 7

7 VERT $\angle$ FWD STA $\rightarrow$ STA WITH SIGN REVERSED

25 5

8 ALGEBRAIC SUM (6)+(7)

51 2

9 $\angle$ SUM = RECIPROCAL VERT $\angle$ STA $\rightarrow$ FWD STA

25 6

10 LOG TAN VERT $\angle$ STA $\rightarrow$ FWD STA { RECIPROCAL (9) NON-RECIP (6) }

8 400 332

STATION LISTEN

552 820 9

3 834 018 6

387 4

742 5

685 4

25 4

412 8

TO COMPUTE SIDE CA

1 UTM LOG BASE RC (If BC is taped, mark block to right)

3 075 729

2 LOG SIN A

9 984 917

3 (1)-(2)

3 090 812

4 TO COMPUTE SIDE CA USE LOG SIN B RA USE LOG SIN C

9 913 699

5 (3)+(4) = LOG SIDE CA RA

3 004 511

TO COMPUTE SIDE CB

1 UTM LOG BASE RC (If BC is taped, mark block to right)

3 075 729

2 LOG SIN A

9 984 917

3 (1)-(2)

3 090 812

4 TO COMPUTE SIDE CB USE LOG SIN B RA USE LOG SIN C

9 913 699

5 (3)+(4) = LOG SIDE CB RA

3 004 511

TO FIND STATION ANGLE AT C

159° 59' 60"

OR 160 00

- CORRECTED $\angle$ C

888 00

STATION ANGLE AT C

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DE- $\angle$ C

DE- $\angle$ C

DE- $\angle$ C

DE- $\angle$ C

360°

6400 M

840 08

3200 M

40 40 8

40 40 8

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51 2

9 $\angle$ SUM = RECIPROCAL VERT $\angle$ STA $\rightarrow$ FWD STA

25 6

10 LOG TAN VERT $\angle$ STA $\rightarrow$ FWD STA { RECIPROCAL (9) NON-RECIP (6) }

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3 090 812

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9 913 699

5 (3)+(4) = LOG SIDE CB RA

3 004 511

TO FIND STATION ANGLE AT C

159° 59' 60"

OR 160 00

- CORRECTED $\angle$ C

888 00

STATION ANGLE AT C

55 12 00

DE- $\angle$ C

DE- $\angle$ C

DE- $\angle$ C

DE- $\angle$ C

360°

6400 M

840 08

3200 M

40 40 8

40 40 8

LOG SIN

3 004 511

LOG COS

9 866 202

SUM = LOG DE

2 870 713

LOG SIDE REPEAT(S)

3 004 511

LOG COS BEARING

9 836 419

SUM = LOG GH

1 404 843

6 VERT $\angle$ STA $\rightarrow$ FWD STA

25 7

7 VERT $\angle$ FWD STA $\rightarrow$ STA WITH SIGN REVERSED

25 5

8 ALGEBRAIC SUM (6)+(7)

51 2

9 $\angle$ SUM = RECIPROCAL VERT $\angle$ STA $\rightarrow$ FWD STA

25 6

10 LOG TAN VERT $\angle$ STA $\rightarrow$ FWD STA { RECIPROCAL (9) NON-RECIP (6) }

8 400 332

STATION LISTEN

552 820 9

3 834 018 6

387 4

742 5

685 4

25 4

412 8

TO COMPUTE SIDE CA

1 UTM LOG BASE RC (If BC is taped, mark block to right)

3 075 729

2 LOG SIN A

9 984 917

3 (1)-(2)

3 090 812

4 TO COMPUTE SIDE CA USE LOG SIN B RA USE LOG SIN C

9 913 699

5 (3)+(4) = LOG SIDE CA RA

3 004 511

Figure 101. Solution of a single triangle, fifth-order survey.

AUXILIARY COMPUTATION										TO COMPUTE SIDE CA		STATION	
	STATION	OBSERVED ANGLES	CORRECTION	CORRECTED ANGLES	1	USE LOG BASE BC				REAR STA → FWD STA	+		
	A			A		LOG SIN A				REAR FWD STA → STA	+		
	B			B		(111-131)				WITH SIGN REVERSED	-		
	C			C						ALGEBRAIC SUM	+		
	SUM OF ANGLES			A+B+C 180° OR 3200"		TO COMPUTE SIDE CA	USE LOG SIN B			RECIPROCAL VERT. ANGLE	+		
					5	LOG SIN C				SUM = STA → FWD STA	+		
					5	(111-131) LOG SIDE CA				LOG TAN VERT. ANGLE	+		
										STA → FWD STA	-		
										LOG SIDE REPEAT IN			
										SUM = LOG OF			
										FORWARD STATION			
										COMPARISON OF SIDE LENGTHS			
										ROUTE 1			
										ROUTE 2			
										DIFFERENCE			

TABLE - CORRECTION FOR CURVATURE AND REFRACTION			
(No interpolation necessary for Artillery Survey)			
Use only when dH is computed using <u>non-Reciprocal</u> vertical angles (Sign always plus).			
LOG SIDE (M)	CORR (M)	LOG SIDE (M)	CORR (M)
3.079	.1	3.712	1.8
3.230	.2	3.736	2.0
3.322	.3	3.784	2.5
3.386	.4	3.824	3.0
3.435	.5	3.857	3.5
3.473	.6	3.886	4.0
3.508	.7	3.912	4.5
3.537	.8	3.934	5.0
3.582	.9	3.955	5.5
3.584	1.0	3.974	6.0
3.625	1.2	3.992	6.5
3.658	1.4	4.007	7.0
3.687	1.6		

GIVEN:
Coordinates and Height of STATION.
Azimuth STATION to REAR STATION.

FIELD DATA:
Observe horizontal angles A, B, and C.
Observe vertical angles to all stations of triangle.
Measure height of target (to the nearest 0.1 meter) if vertical angles are measured at a point other than H1.
Tape base (BC) unless known from other computations.

GUIDE:
Enter field data in blocks marked.
BC is always the known base.
REAR STATION is station in triangle to which azimuth is known.
STATION is the station for which survey control is known.
FORWARD STATION is the station for which survey control is desired.
RECIPROCAL ANGLE is the mean of the vertical angles observed from each end of a side.
NON-RECIPROCAL ANGLE is a vertical angle which has been measured from station to forward station only.
Best results are obtained when RECIPROCAL ANGLES are used to compute height.
Divide the difference between SUM OF ANGLES and $\frac{(180^\circ)}{(3200'')}$ into three parts and apply as CORRECTION to the OBSERVED ANGLES to obtain CORRECTED ANGLES.
Compute the side (CA or BA) which forms the base of the next triangle.

LIMITATIONS
DISTANCE ANGLES (angles opposite the known base and the computed side) should be greater than $\frac{(22 \frac{1}{2}^\circ)}{(400')}$ or accuracy may fall below standard.
When reciprocal or non-reciprocal angles are measured to a height of target other than H1 use DA Form 6-2b to compute height.

RESULTS:
Coordinates and height of FORWARD STATION.
Azimuth from FORWARD STATION (A) to STATION (B or C).

FORMULAS:
Side CA = $\frac{\text{base BC}}{\sin A} \times \sin B$; Side BA = $\frac{\text{base BC}}{\sin A} \times \sin C$

Figure 102. Back of DA Form 6-8.

and the sum of the interior angles must be 180° . However, as actually measured in the field, the sum of the angles will usually vary from 180° by a few seconds. If this amount is within tolerance (app II), the angles are adjusted to equal 180° . This is done by distributing the closure correction (the closure error with the sign reversed) equally among the three angles. The remainder is applied to the larger angle(s). The following example illustrates the procedure for adjusting the angles of a triangle:

Measured angles	Correction	Corrected angles
A = $54^\circ 07' 29''$	----- $-1''$ -----	$54^\circ 07' 28''$
B = $78^\circ 30' 27''$	----- $-2''$ -----	$78^\circ 30' 25''$
C = $47^\circ 22' 08''$	----- $-1''$ -----	$47^\circ 22' 07''$
Sum = $180^\circ 00' 04''$		Sum = $180^\circ 00' 00''$

248. DA Form 6-8

a. DA Form 6-8 (figs. 101 and 102) is used for the computation of triangulation schemes. In computing single triangles or chains of single triangles, only the front side of the form is used. In computing quadrilaterals, both the front and back sides of the form are used (par. 253). It is of prime importance to insure that proper orientation is made of the triangle to be computed in the triangular sketch on the front of the form. The known base of the triangle to be computed must always be represented on the sketch as in line CB. A sample computation is shown in figure 101.

b. Entries required are as shown in figure 101 and appendix II.

c. Formulas to be used are shown on the back of the form (fig. 102).

249. Height Determination in Triangulation

a. Vertical angles at each end of a side should be measured reciprocally to the height of instrument (HI). Frequently, due to distances involved, the instrument operator must measure the vertical angle to a target erected over the forward station. When the vertical angles are measured reciprocally at HI, the heights of triangulation stations are computed on the DA Form 6-8. If the length of the side is greater than 1,000 meters and/or if the vertical angle is not measured reciprocally, the

table of curvature and refraction corrections on the reverse side of DA Form 6-8 must be used. To enter the table, use the log length of the side along which the height is being extended.

b. When the vertical angle is measured to a target erected over the station or to any point other than height of instrument, the height of the unknown station is computed on DA Form 6-2b (fig. 90). Complete instructions for the use of DA Form 6-2b are contained on the reverse side of the form (fig. 91). At each station, the height of instrument and the heights of any points which could conceivably be used as a target by other parties will be recorded. Prior to performing the computations, the parties compare notes and determine the heights of targets and heights of instruments to be used.

c. In any triangulation scheme, the coordinates and height of at least one station must be known. This station is used as the starting point to obtain the height of the next station. The height control is extended along the forward line of each triangle in the scheme. In figure 103, using the height of point C as a starting point, the height of point B is first determined since the height of point A must be computed along the forward line, BA. Once the height of B is determined, the height of A can be determined. Using the height of A, the height of D is computed and from D, the height of E is determined.

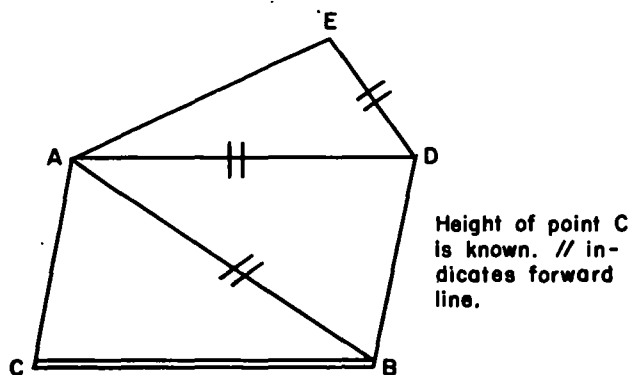


Figure 103. Schematic drawing showing route of trigonometric height computations.

Section III. QUADRILATERALS

250. General

A quadrilateral is a triangulation scheme. The difference between a quadrilateral scheme and a single chain of triangles scheme is that in a quadrilateral two interior angles are measured at each point, resulting in two diagonals as shown in figure 104. In effect, the result is two single chains of two triangles each, one superimposed on the other; if separated, they would appear as two single chains of triangles

as shown in figure 105. Triangles ABC and ACD form one chain, and triangles ABD and BCD form the other. It is apparent that if side DC were of known length and side AB were the desired side (forward line), the length of side AB could be computed through two separate schemes, thus introducing a check feature into the fieldwork and computations. For this reason, the quadrilateral scheme is preferred over the single chain of triangles.

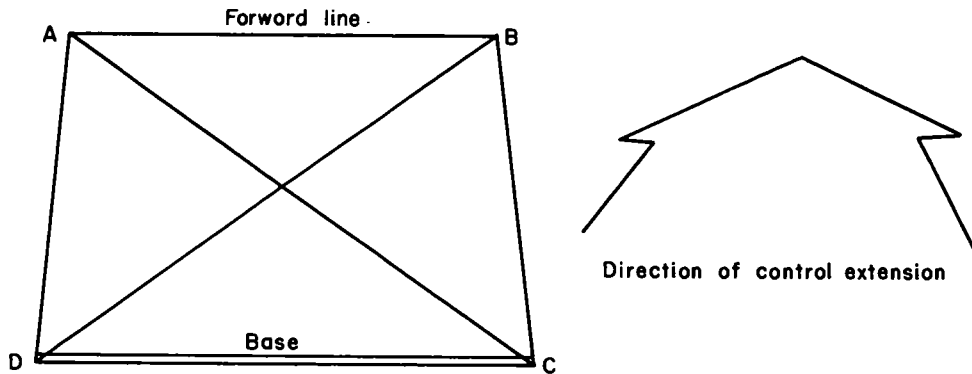


Figure 104. Schematic drawing of a quadrilateral.

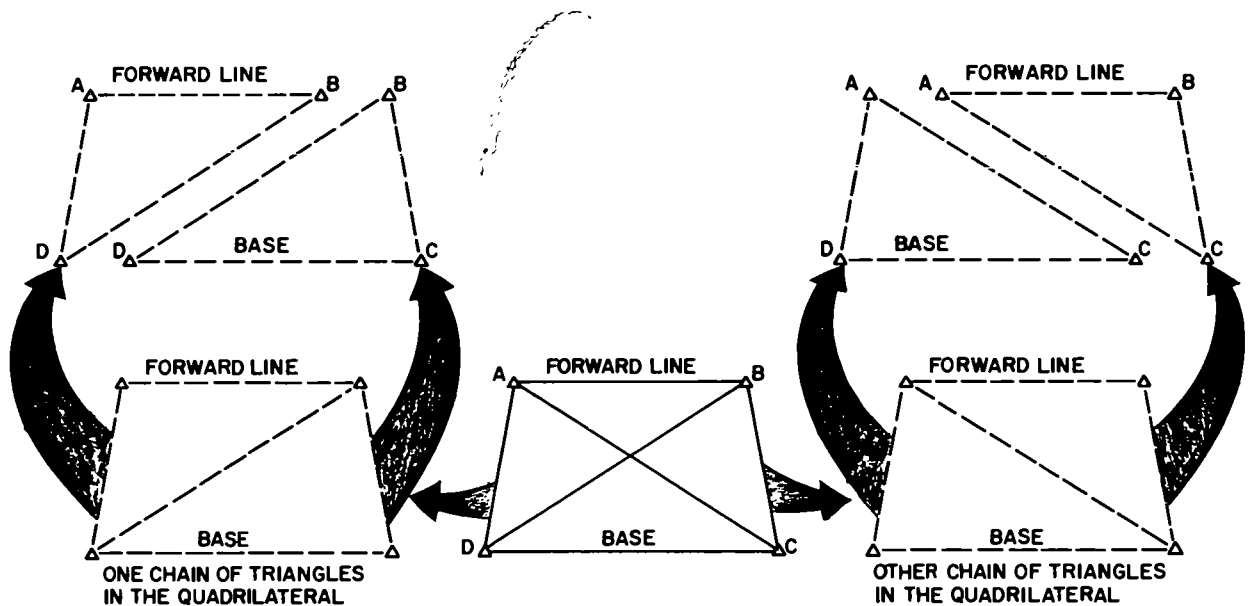


Figure 105. Schematic drawing of a quadrilateral separated into two single chains of two triangles each.

251. Fieldwork for Quadrilaterals

Since any quadrilateral is basically a network of triangles and the computations will follow the same general form as those for single triangles, the requirements for fieldwork are similar to those previously mentioned. The distance angles must be greater than $22\frac{1}{2}^{\circ}$ (400 mils) and less than $157\frac{1}{2}^{\circ}$ (2,800 mils) and preferably between 30° and 150° (533 mils and 2,667 mils). The specifications for desired accuracy are identical to those tabulated for triangulation (app. II).

252. Determining the Forward Line

When a quadrilateral is computed, it is reduced to single triangles, and each triangle is computed separately. First, the azimuth and length of the base must be determined; second, coordinates and height of one station in the scheme must be known; third, the values of the interior angles and vertical angles at each station must be measured; and fourth, the forward line must be determined in order that its length may be computed. In a single quadrilateral, the forward line is always the side opposite the known side, or the side in the direction in which control is being extended (fig. 104). If the scheme contains a chain of quadrilaterals, the forward line is that side which is common to adjacent quadrilaterals.

253. Strength of Figures

Assume that the quadrilateral in figure 104 is to be computed. The coordinates of points C and D are known, so the azimuth and length of the base can be computed on a DA Form 6-1. Each point is then occupied, and the interior and vertical angles are measured. Since side CD is the known side, the opposite side (AB) will be the forward line. The basic quadrilateral (fig. 104) is really two single chains of triangle (fig. 105). It would be possible to compute through both chains and arrive at the coordinates and height of points A and B and the distance between them, averaging the results to obtain a final answer. However, this method would not only be time-consuming but could produce highly inaccurate results. By use of strength of figures, one chain is chosen as the principal route (R1) through which the coordinates and length of the forward line is computed. The other chain

provides another route (R2) by which only the length of the forward line is determined. If the two log lengths in DA Form 6-8 agree within five digits in the fifth decimal place (0.0000500) of the mantissa, then the fieldwork and the computations are assumed to be correct. If they do not agree within the tolerance, then an excessive error has been made, and the work must be rechecked.

254. Distance Angles

The strength of the distance angles in the chain will determine which chain is to be R1 and which is to be R2. The chain containing the stronger combination of distance angles will produce the more accurate answer and will be the R1 chain. The weaker chain will be the R2 chain. To determine the stronger chain, a table may be used (figs. 106 and 107). The two distance angles of each triangle, rounded off to the nearest degree or mil indicated in the figures, are used to enter the appropriate chart. The factors obtained for each triangle of a given chain are then added, and the chain containing the smaller total value is the stronger, or R1, chain. Figure 108 illustrates the determination of the R1 and R2 chains. When the distance angles are used to enter the strength of figure table, the relative strength of the chain on the left is found to be 5 and the relative strength of the chain on the right is found to be 6. The chain on the left is the R1 chain.

255. Computation of Quadrilaterals

DA Form 6-8 is used to compute quadrilaterals (figs. 109 and 110). One form is used to compute each quadrilateral. The R1 chain is computed on the front of the form and the R2 chain is computed on the back. Only the log distance of the forward line is sought from the R2 chain. In solving quadrilaterals, first compute the log length of the forward line through both chains. If the log lengths agree within 5 in the fifth place of the mantissa, the fieldwork and computations up to that point are correct. Computation may then be continued to solve for the desired coordinates. This procedure will save time, in that if the log lengths do not agree, the previous work must be rechecked, and the solution for the coordinates would not have to be redone, which would be the case if the entire front of the

	10°	12°	14°	16°	18°	20°	25°	30°	35°	40°	45°	50°	55°	60°	65°	70°	75°	80°	85°	90°
10	428	359																		
12	359	259	253																	
14	315	253	214	187																
16	284	225	187	162	143															
18	262	204	168	143	126	113														
20	245	180	153	130	113	100														
22	232	177	142	119	103	91														
24	221	167	134	111	95	83	64													
26	213	160	126	104	89	77	58													
28	206	153	120	99	83	72	54	43												
30	199	148	115	94	79	68	50	40	33											
35	188	137	106	85	71	60	44	33	27	23										
40	179	129	99	79	65	54	38	29	23	19	16									
45	172	124	93	74	60	50	34	25	20	16	13	11								
50	167	119	89	70	57	47	32	23	18	14	11	9	8							
55	162	115	86	67	54	44	30	21	16	12	10	8	7	5						
60	159	112	83	64	51	42	28	19	14	11	9	7	5	4	4					
65	155	109	80	62	49	40	26	18	13	10	7	6	5	4	3	2				
70	152	106	78	60	48	38	25	17	12	9	7	5	4	3	2	2	1			
75	150	104	76	58	46	37	23	16	11	8	6	4	3	2	2	1	1	1		
80	147	102	74	57	45	36	22	15	10	7	5	4	3	2	1	1	1	1	0	0
85	145	100	73	55	43	34	21	14	10	7	5	3	2	2	1	1	1	0	0	0
90	143	98	71	54	42	33	20	13	9	6	4	3	2	1	1	1	0	0	0	0
95	140	96	70	53	41	32	20	13	9	6	4	3	2	1	1	0	0	0	0	
100	138	95	68	51	40	31	19	12	8	6	4	3	2	1	1	0	0	0		
105	136	93	67	50	39	30	18	12	8	5	4	2	2	1	1	0	0			
110	134	91	65	49	38	30	18	11	7	5	3	2	2	1	1					
115	132	89	64	48	37	29	17	11	7	5	3	2	2	1	1					
120	129	88	62	46	36	28	16	10	7	5	3	2	2	1						
125	127	86	61	45	35	27	16	10	7	5	4	3	2							
130	125	84	59	44	34	26	16	10	7	5	4	3								
135	122	82	58	43	33	26	16	10	7	5	4									
140	119	80	56	42	32	25	16	10	8	6										
145	116	77	55	41	32	25	16	11	9											
150	112	75	54	40	32	26	17	13												
152	111	75	53	40	32	26	18													
154	110	74	53	41	33	27	20													
156	108	74	54	42	34	28														
158	107	74	54	43	35	30														
160	107	74	56	45	38	33														
162	107	76	59	48	42															
164	109	79	63	54																
166	113	86	71																	
168	122	98																		
170	143																			

Figure 106. Table for determining strength of figure factors (degrees)

form had been completed before proceeding to the back of the form.

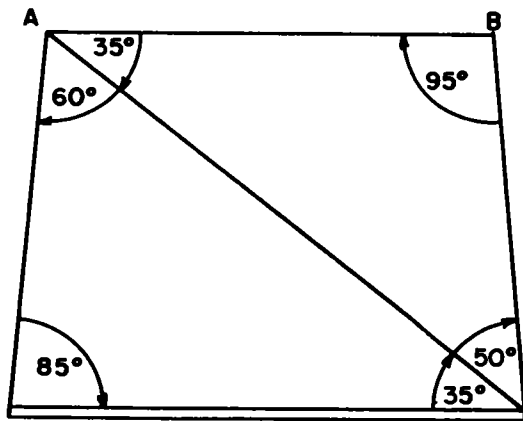
a. *Coordinate Computations.* In a single chain of triangles, the forward line in the last triangle of the chain is always opposite the stronger angle. In a chain of quadrilaterals, the last forward line is in the R1 chain, and it may or may not be opposite the stronger angle in the last triangle. However, because

of the check obtained through the comparison of the R1 and the R2 chains, the accuracy of the coordinates obtained is assured.

b. *Height Computations.* Height computations in quadrilateral schemes usually involve distances in excess of 1,000 meters, which require determination of heights by use of DA Form 6-2b. For additional information see paragraph 249.

Mils	150	200	250	300	350	400	450	500	550	600	700	800	900	1000	1100	1200	1300	1400	1500	1600
150	605																			
200	465	334																		
250	391	272	212																	
300	347	233	176	143																
350	320	210	155	123	104															
400	300	192	139	109	91	78														
450	283	178	127	97	80	68	58													
500	272	169	119	90	73	61	52	46												
550	264	162	112	84	68	56	47	41	37											
600	257	157	108	80	64	53	44	38	34	31										
700	245	147	99	72	57	46	38	32	28	25	20									
800	236	139	93	67	52	41	33	28	24	21	17	13								
900	229	133	88	62	48	38	30	25	21	19	14	11	9							
1000	223	129	84	59	45	35	27	23	19	17	12	9	7	6						
1100	218	125	81	56	43	33	25	21	17	15	11	8	6	5	4					
1200	215	123	79	55	41	31	24	20	16	14	10	7	5	4	3	2				
1300	211	119	76	52	39	29	22	18	15	13	9	6	4	3	2	2	1			
1400	207	117	74	51	37	28	21	17	14	12	8	5	4	3	2	1	1	0		
1500	205	115	72	49	36	27	20	16	13	11	7	5	3	2	1	1	1	0	0	
1600	202	112	71	48	35	26	19	15	12	10	7	4	3	2	1	1	1	0	0	0
1700	199	110	69	46	34	25	19	14	12	10	6	4	3	2	1	1	1	0	0	0
1800	196	108	67	45	33	24	18	14	11	9	6	4	2	2	1	1	1	0	0	
1900	193	106	66	44	32	23	17	13	11	9	6	4	2	1	1	1	1	0		
2000	190	104	64	42	30	22	16	13	10	8	5	3	2	2	1	1	1			
2100	187	102	63	41	30	22	16	12	10	8	5	3	2	2	1					
2200	184	99	61	40	29	21	15	12	9	8	5	3	2	2						
2300	180	97	59	39	28	20	15	11	9	8	5	4	3							
2400	176	95	57	38	27	20	15	11	9	8	6	4								
2500	171	92	55	36	26	20	15	12	10	9	7									
2600	166	89	54	36	26	20	16	13	11	10										
2650	164	88	53	36	26	20	16	14	12											
2700	161	86	53	36	27	21	17	15												
2750	159	85	53	37	28	23	19													
2800	155	84	54	38	31	26														
2850	153	85	56	42	35															
2900	151	87	60	48																
2950	153	94	71																	
3000	163	112																		
3050	202																			

Figure 107. Table for determining strength of figure factors (mils).

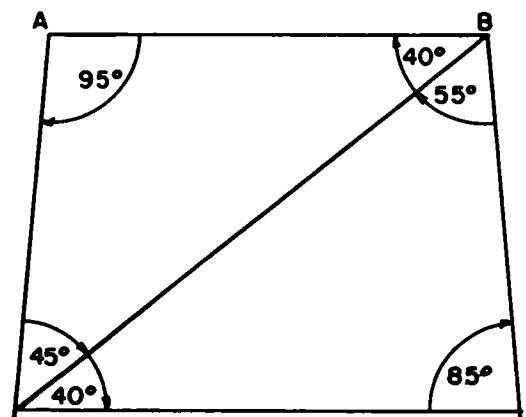


$$\text{Distance angles} = 85^\circ - 60^\circ = 2$$

$$\text{Distance angles} = 95^\circ - 50^\circ = 3$$

$$\text{Total strength of figures} = 5$$

R1



$$\text{Distance angles} = 85^\circ - 55^\circ = 2$$

$$\text{Distance angles} = 95^\circ - 45^\circ = 4$$

$$\text{Total strength of figures} = 6$$

R2

Figure 108. Schematic drawing showing the determination of R1 and R2 chains.

1-16-58

Figure 109. Solution of R1 chain, fourth-order survey.

AUXILIARY COMPUTATION										
					TO COMPUTE SIDE CA					
	STATION	OBSERVED ANGLES	CORRECTION	CORRECTED ANGLES	1	UTM LOG BASE BC	3 790 3792	STATION		
	A	SCP 4	45 42 51	-1	45 42 50	1	LOG SH A	9 854 8293	VERT. Δ STA	FWD STA
	B	SCP 2	66 30 53	-2	66 30 51	1	LOG SH B	3 935 5499	VERT. Δ FWD STA	STA
	C	SCP 1	67 46 21	-2	67 46 19	1	TO COMPUTE SIDE CA	9 962 4444	ALGEBRAIC SUM	
	SUM OF ANGLES	180 00 05		180 00 00	1	171.741 LOG SIDE	3 897 9943	RECIPROCAL VERT. Δ		
					1			LOG TAN VERT. Δ		
					1			LOG TAN VERT. Δ		
					1			LOG SIDE (BASE + 1/2)		
					1			SUM LOG SH		
					1			FORWARD STATION		
					1			COMPARISON OF SIDE LENGTH		
					1			ROUTE 1	3 534 8363	
					1			ROUTE 2	3 534 8395	
					1			DIFFERENCE	0 000 0032	

TABLE - CORRECTION FOR CURVATURE AND REFRACTION			
(No interpolation necessary for Artillery Survey) Use <u>only</u> when dH is computed using non-Reciprocal vertical angles (Sign always plus).			
LOG SIDE (M)	CORR (M)	LOG SIDE (M)	CORR (M)
3.079	.1	3.712	1.8
3.230	.2	3.738	2.0
3.322	.3	3.784	2.5
3.386	.4	3.824	3.0
3.435	.5	3.857	3.5
3.473	.6	3.888	4.0
3.508	.7	3.912	4.5
3.537	.8	3.934	5.0
3.562	.9	3.955	5.5
3.584	1.0	3.974	6.0
3.625	1.2	3.992	6.5
3.658	1.4	4.007	7.0
3.687	1.6		

GIVEN:
Coordinates and Height of STATION.
Azimuth STATION to REAR STATION.

FIELD DATA:
Observe horizontal angles A, B, and C.
Observe vertical angles to all stations of triangle.
Measure height of target (to the nearest 0.1 meter) if vertical angles are measured at a point other than HL Tape base (BC) unless known from other computations.

GUIDE:
Enter field data in blocks marked.
BC is always the known base.
REAR STATION is station in triangle to which azimuth is known.
STATION is the station for which survey control is known.
FORWARD STATION is the station for which survey control is desired.
RECIPROCAL ANGLE is the mean of the vertical angles observed from each end of a side.
NON-RECIPROCAL ANGLE is a vertical angle which has been measured from station to forward station only.
Best results are obtained when RECIPROCAL ANGLES are used to compute height.
Divide the difference between SUM OF ANGLES and (180°) into three parts and apply as CORRECTION to the OBSERVED ANGLES to obtain CORRECTED ANGLES.
Compute the side (CA or BA) which forms the base of the next triangle.

LIMITATIONS
DISTANCE ANGLES (angles opposite the known base and the computed side) should be greater than $(22 \frac{1}{2}^\circ)$ or accuracy may fall below standard.
When reciprocal or non-reciprocal angles are measured to a height of target other than H1 use DA Form 6-2b to compute height.

RESULTS:
Coordinates and height of FORWARD STATION.
Azimuth from FORWARD STATION (A) to STATION (B or C).

FORMULAS:
Side CA = $\frac{\text{base BC}}{\sin A} \times \sin B$; Side BA = $\frac{\text{base BC}}{\sin A} \times \sin C$

Figure 110. Solution of R2 chain, fourth-order survey.

256. Sequence in Quadrilateral Computations

The proper steps to take in computing a quadrilateral are as follows:

- Isolate the quadrilateral from the quadrilateral scheme.
- Determine the R1 and R2 chains.

- Compute the R1 chain on the front of DA Form 6-8.
- Compute the R2 chain on the back of DA Form 6-8.
- Compare the log distance of the forward line.
- Determine coordinates, using the R1 chain.
- Determine heights, using DA Form 6-2b.

Section IV. CENTRAL POINT FIGURES

257. General

When it is impossible to observe the diagonals of a quadrilateral, the central point is used. Two central point figures commonly used are shown in figures 111 and 112. Central point figures of six or more sides are not generally used because of the excessive time and the number of personnel required to accomplish the fieldwork.

258. Computation of Central Point Figures

The solution of the central point scheme is similar to the solution of the basic quadrilateral. The R1 and the R2 chains must be

determined. In figures 111 and 112, each scheme contains two chains of triangles, one going clockwise around the central point and the other going counterclockwise. In figure 112 if AB were the base and DC the forward line, the chain of triangles going clockwise would contain four triangles and the other chain of triangles going counterclockwise would contain only three triangles. However, the relative strength of the chain of four triangles may make it the R1 chain when it is compared to the relative strength of the chain of only three triangles.

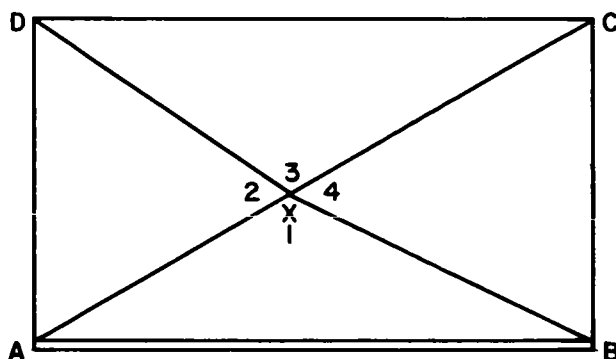


Figure 111. Central point quadrilateral.

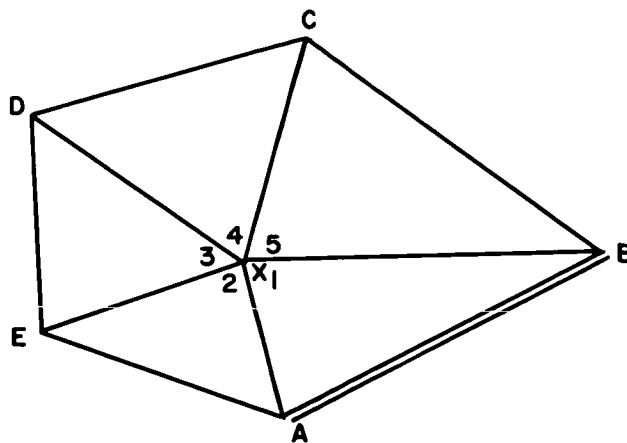


Figure 112. Central point pentagon.

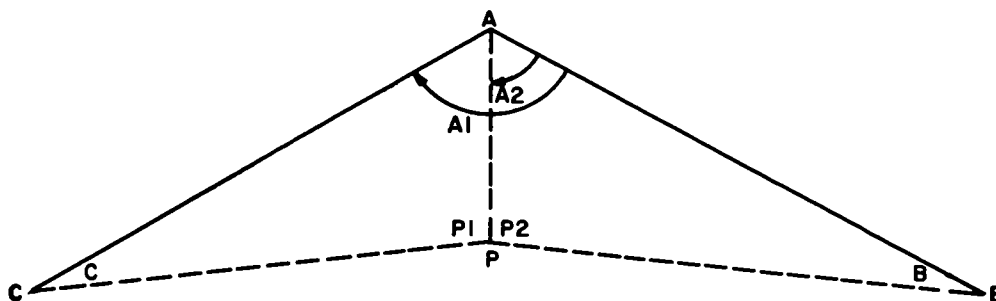


Figure 113. Schematic drawing of a three-point resection.

COMPUTATION—COORDINATES AND HEIGHT FROM THREE-POINT RESECTION									
1	AZIMUTH A TO C (FROM AUX COMP ON REV)		104 24 04		SKETCH				
2	360° OR 6400d								
2	IF (1) IS MORE THAN (4) REPEAT (1) LESS THAN (4) (1) + (2)		104 24 04						
4	AZIMUTH A TO B (FROM AUX COMP ON REV)		82 12 38						
5	(5) - (4) = ANGLE A ₁		22 11 26		IF (14) IS MORE THAN (17) 18 REPEAT (14) 3 815 4261 19 REPEAT (17) 3 733 9123 20 (18) - (19) 0 081 5138 21 ANGLE HAVING LOG TAN (20) 50 20 45 22 45° OR 800d 45 00 00 23 (21) - (22) 5 20 45 24 LOG TAN (23) 8 971 1556 25 LOG TAN (11) 0 453 7562 26 (24) + (25) 9 424 9118 27 REPEAT (11) 109 22 47 28 ANGLE HAVING LOG TAN (26) 14 53 48 IF (27) IS MORE THAN 90° (27) + (28) 124 16 35 LESS THAN 90° 30 IS (27) - (28) 94 28 59 IF (14) IS LESS THAN (17) 21 ANGLE HAVING LOG TAN (20) 22 45° OR 800d 23 (21) - (22) 24 LOG TAN (23) 25 LOG TAN (11) 26 (24) + (25) 27 REPEAT (11) 28 ANGLE HAVING LOG TAN (26) IF (27) IS MORE THAN 90° (27) + (28) LESS THAN 90° 30 IS (27) - (28)				
6	OBSERVED ANGLE P ₁		48 00 50						
7	OBSERVED ANGLE P ₂		71 02 10						
8	(5) + (6) + (7) DO NOT ATTEMPT TO SOLVE PROBLEM WHEN THIS VALUE IS BETWEEN { 160° } AND { 555d }		141 14 26						
9	180° OR 5200d		179 59 60		18 REPEAT (14) 3 815 4261 19 REPEAT (17) 3 733 9123 20 (18) - (19) 0 081 5138 21 ANGLE HAVING LOG TAN (20) 50 20 45 22 45° OR 800d 45 00 00 23 (21) - (22) 5 20 45 24 LOG TAN (23) 8 971 1556 25 LOG TAN (11) 0 453 7562 26 (24) + (25) 9 424 9118 27 REPEAT (11) 109 22 47 28 ANGLE HAVING LOG TAN (26) 14 53 48 IF (27) IS MORE THAN 90° (27) + (28) 124 16 35 LESS THAN 90° 30 IS (27) - (28) 94 28 59 IF (14) IS LESS THAN (17) 21 ANGLE HAVING LOG TAN (20) 22 45° OR 800d 23 (21) - (22) 24 LOG TAN (23) 25 LOG TAN (11) 26 (24) + (25) 27 REPEAT (11) 28 ANGLE HAVING LOG TAN (26) IF (27) IS MORE THAN 90° (27) + (28) LESS THAN 90° 30 IS (27) - (28)				
10	1/2 OF (8)		70 37 13						
11	(9) - (10)		109 22 47						
12	LOG GRID DISTANCE A TO C (FROM AUX COMP ON REV)		3 839 6619						
13	LOG SIN (7)		9 975 7642						
14	(12) + (13)		3 815 4261						
15	LOG GRID DISTANCE A TO B (FROM AUX COMP ON REV)		3 862 7441						
16	LOG SIN (6)		9 871 1682						
17	(15) + (14)		3 733 9123						
REAR STATION B AZ A TO B REPEAT (4) 82 12 38 STA ANGLE REPEAT (36) 14 28 51 SUM 96 41 29 - 360° 96 41 29 AZIMUTH A TO F 96 41 29 (+ 180° 96 41 29) AZIMUTH F TO A AZ TO BEARING 179 59 60 96 41 29 BEARING 83 18 31 REPEAT (51) 3 885 6483 LOG SIN BEARING 9 997 0316 SUM LOG 3 882 6799 STATION A PAC VERT A TO A WITH SIGN REVERSED 0 21 30 LOG TAN VERT 7 796 1702 REPEAT (51) 3 885 6483 LOG COS BEARING 9 066 4059 SUM LOG 2 952 0542									
* DIFFERENCE IN HEIGHTS OF TARGET AND INSTRUMENT FROM GROUND ON REVERSE ** CORRECTION FOR CURVATURE AND REFRACTION FROM TABLE ON REVERSE STATION P OI COMPUTER Cpl Webb E 546 702 94 N 3 836 848 87 W 329 4 S 27 632 73 N 895 48 W 48 1 LOG TAN VERT 7 796 1702 REPEAT (51) 3 885 6483 LOG COS BEARING 9 066 4059 SUM LOG 2 952 0542 E 554 335 67 N 3 835 953 39 W 373 5									
51 REPEAT (50) 94 28 59 52 REPEAT (7) 71 02 10 53 (51) + (52) 165 31 09 54 180° OR 5200d 179 59 60 55 REPEAT (25) 165 31 09 56 (54) - (55) = ANGLE A₂ 14 28 51 57 REPEAT (15) 3 862 7441 58 LOG SIN (30) 9 998 6693 59 (57) + (58) 3 861 4134 60 REPEAT (13) 9 975 7642 61 (59) - (60) 3 885 6492 62 REPEAT (12) 3 839 6619 63 LOG SIN (29) 9 917 1538 64 (62) + (63) 3 756 8157 65 REPEAT (16) 9 871 1682 66 (64) - (65) 3 885 6475 67 REPEAT (41) 3 885 6492 68 DIFFERENCE BETWEEN (64) AND (67) [MUST BE LESS THAN 0.0001] 0 000 0017 69 1/2 OF (68) 0 000 0008 70 REPEAT (46) OR (47) WHICHEVER IS SMALLER 3 885 6475 71 (69) + (70) = LOG GRID DISTANCE A TO P 3 885 6483 DATE 16 Jan 1958 AREA Font 10-58 1-10-58									

DA FORM 6-19

PREVIOUS EDITIONS OF THIS FORM ARE OBSOLETE

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Figure 114. Solution of three-point resection, fourth-order survey.

AUXILIARY COMPUTATION AZIMUTH AND DISTANCE FROM A TO B AND A TO C					
STATION		E COORDINATE		N COORDINATE	
FROM STATION A	PAC	A 546 702 94	A	3 836 848 87	
TO STATION B	MAN	B 553 925 95	B	3 837 836 95	
IF A IS LESS THAN B REPEAT A	AA	546 702 94	AA	3 836 848 87	
IF AA IS BLANK, USE A-B, SIGN- IF AA IS FILLED, USE B-AA, SIGN+	4E	+ 7 223 01	4N	+ 988 08	
LOG 4E		3.858 7182	ANGLE HAVING LOG TAN BEARING A TO B		82 12 38
LOG 4N		2.994 7921	DETERMINE AZIMUTH FROM BEARING BY PUTTING 4E AND 4N ON SKETCH AS GUIDE		
LOG 4E - LOG 4N = LOG TAN BEARING A TO B		0.863 9261	AZIMUTH A TO B (ENTER IN (4) ON FRONT)		82 12 38
IF 4E IS MORE THAN 4N		IF 4E IS LESS THAN 4N			
REPEAT LOG 4E		3.858 7182	REPEAT LOG 4N		
LOG SIN BEARING A TO B		9.995 9741	LOG COS BEARING A TO B		
LOG 4E - LOG SIN BEARING = LOG GRID DISTANCE A TO B		3.862 7441	LOG 4N - LOG COS BEARING = LOG GRID DISTANCE A TO B		
[ENTER LOG GRID DISTANCE A TO B IN (15) ON FRONT]					
STATION		E COORDINATE		N COORDINATE	
FROM STATION A	PAC	A 546 902 94	A	3 836 848 87	
TO STATION C	REY	C 553 398 65	C	3 835 129 58	
IF A IS LESS THAN C REPEAT A	AA	546 902 94	AA		
IF AA IS BLANK, USE A-C, SIGN- IF AA IS FILLED, USE C-AA, SIGN+	4E	+ 6 695 71	4N	+ 1 719 29	
LOG 4E		3.825 7966	ANGLE HAVING LOG TAN BEARING A TO C		75 35 56
LOG 4N		3.235 3492	DETERMINE AZIMUTH FROM BEARING BY PLOTTING 4E AND 4N ON SKETCH AS GUIDE		179 59 60
LOG 4E - LOG 4N = LOG TAN BEARING A TO C		0.590 4474	AZIMUTH A TO C (ENTER IN (1) ON FRONT)		75 35 56
IF 4E IS MORE THAN 4N		IF 4E IS LESS THAN 4N			
REPEAT LOG 4E		3.8257966	REPEAT LOG 4N		
LOG SIN BEARING A TO C		9.9861347	LOG COS BEARING A TO C		
LOG 4E - LOG SIN BEARING = LOG GRID DISTANCE A TO C		3.8396619	LOG 4N - LOG COS BEARING = LOG GRID DISTANCE A TO C		
[ENTER LOG GRID DISTANCE A TO C IN (12) ON FRONT]					

TABLE - CORRECTION FOR CURVATURE AND REFRACTION
(NO INTERPOLATION NECESSARY FOR ARTILLERY SURVEY)

(SIGN ALWAYS MINUS)			
Log Side (M)	Corr (M)	Log Side (M)	Corr (M)
3.079	.1	3.712	1.8
3.230	.2	3.736	2.0
3.322	.3	3.784	2.5
3.386	.4	3.824	3.0
3.435	.5	3.857	3.5
3.473	.6	3.886	4.0
3.508	.7	3.912	4.5
3.537	.8	3.934	5.0
3.562	.8	3.955	5.5
3.584	1.0	3.974	6.0
3.625	1.2	3.992	6.5
3.658	1.4	4.007	7.0
3.687	1.6		

GIVEN:
Coordinates of stations A, B, and C.
Height of station A.

FIELD DATA:
Observe horizontal angles P_1 and P_2 .
Observe vertical angle to station A.
Measure height of instrument (to nearest 0.1 meter).
Estimate height of target at station A, if not known.

GUIDE:
Enter observed field data in blocks marked .
When value in (B) of computation is between 160° (2845d) and 200° (3555d), a new station P or new stations A, B, and/or C must be selected.
Find difference between heights of instrument and target as follows.

a	Known or Estimated Height of Target	+	
b	Measured Height of Instrument	-	
c	Algebraic Sum a and b (Enter, with sign, in block marked)		

Enter correction for curvature and refraction in block marked .

LIMITATIONS:
Angles P_1 , P_2 , B, and C should be greater than $22\frac{1}{2}^\circ$ (400d) or accuracy may fall below standard.

RESULTS:
Coordinates and height of station P.
Azimuth from station P to station A.

FORMULAS:

$$\tan Z = \frac{AC \sin P_2}{AB \sin P_1} \quad \text{or} \quad \tan Z = \frac{AB \sin P_1}{AC \sin P_2}$$

$$\text{If } 1/2 (B+C) \text{ is more than } \begin{cases} 90^\circ \\ 1600d \end{cases}: \quad \text{If } 1/2 (B+C) \text{ is more than } \begin{cases} 90^\circ \\ 1600d \end{cases}: \\ \tan 1/2 (C-B) = \tan (Z - 45^\circ) \tan 1/2 (B+C) \quad \tan 1/2 (B-C) = \tan (Z - 45^\circ) \tan 1/2 (B+C) \\ \text{If } 1/2 (B+C) \text{ is less than } \begin{cases} 90^\circ \\ 1600d \end{cases}: \quad \text{If } 1/2 (B+C) \text{ is less than } \begin{cases} 90^\circ \\ 1600d \end{cases}: \\ \tan 1/2 (B-C) = \tan (Z - 45^\circ) \tan 1/2 (B+C) \quad \tan 1/2 (C-B) = \tan (Z - 45^\circ) \tan 1/2 (B+C)$$

$$AP = \frac{AB \sin B}{\sin P_2} = \frac{AC \sin C}{\sin P_1}$$

Z = an auxiliary angle required only in the computation (always between 45 and 90 degrees).

Figure 115. Back of DA Form 6-19.

259. Three-Point Resection

Three-point resection is a method of obtaining control from three known points which are inaccessible. The fieldwork required for the solution is relatively simple. However, before going into the field, several factors must be considered. In figure 113, points A, B, and C are the known points and point P is the occupied station for which coordinates are to be determined. A map reconnaissance is of prime importance. All points should be selected so that angles P1, P2, C, and B are at least $22\frac{1}{2}^\circ$ (400 mils) and preferably over 30° (533 mils). In addition, if the sum of the angles P1, P2, and A1 is between 160° and 200° (2,845 mils and 3,555 mils), no valid solution is possible. Fieldwork consists of measuring angles P1 and P2 and the vertical angle from P to whichever known point for which the height is also known, preferably point A.

260. DA Form 6-19

a. DA Form 6-19 is used for the computation of a three-point resection problem (figs. 114 and 115).

b. Entries required are the coordinates of points A, B, and C and the horizontal angles and vertical angle measured at point P.

c. The formulas to be used are shown on the back of the form.

261. Two-Point Resection

Two-point resection is a method of survey similar to three-point resection. In two-point resection, control is obtained from two known

points which are inaccessible. In figure 116 points A and B are the inaccessible points of known survey control. Points R and Q are points from which the other three points are visible. This scheme resembles a quadrilateral, except that the angles at points A and B are not measured. As with three-point resection, certain preliminary operations must be performed. Map reconnaissance is required to insure that all interior angles will be greater than $22\frac{1}{2}^\circ$ (400 mils) and less than $157\frac{1}{2}^\circ$ (2,800 mils) and preferably between 30° and 150° (533 mils and 2,667 mils). Also points A and B must be visible from R and Q as well as R and Q must be intervisible. Fieldwork will consist of measuring angles R1, R2, Q1, and Q2 and vertical angles to A from R and Q.

262. DA Form 6-18

a. DA Form 6-18 (figs. 117 and 118) is used for the computation of a two-point resection problem. If only the coordinates of point R are desired, the section labeled TO LOCATE STATION Q, lines 36 to 40, are not used. Similarly, if only the location of point Q is desired, the section labeled TO LOCATE STATION R, lines 41 to 45, are not used.

b. Entries required are the coordinates of the points A and B and the horizontal and vertical angles at points R and Q.

c. The formulas to be used are shown on the back of the form.

263. Limitations and Use of Resection

Unless a resection (two- or three-point) has been checked by some other means, the general rule is that it cannot be used as a point from which to extend survey control. However, a battery center and the 01-02 target area base of a field artillery battalion could be located by using a two-point or three-point resection. If known points are available, resection probably would allow these points to be located more rapidly than traversing and would allow the unit to conduct unobserved fire much sooner. If necessary, corrections could be made later by traversing to a known point. Also, resection could be used to locate any single point, to check a location determined by some other means of survey, or to verify points of suspected known control.

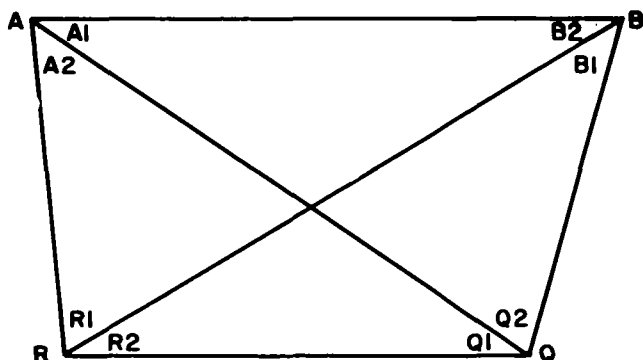


Figure 116. Schematic drawing showing two-point resection.

COMPUTATION - COORDINATES AND HEIGHT FROM TWO-POINT RESECTION (TM 6-200)															
1	OBSERVED ANGLE O_1	28	59	50		21	ANGLE HAVING LOG TAN (20)	50	32	51	23	REPEAT (10)	39	30	20
2	OBSERVED ANGLE R_2	52	31	10		22	(21) - (45° 00' 00")	45	00	00	34	REPEAT (29) OR (28), ANGLE B_2	35	58	23
3	(1) + (2)	81	31	00		22	(21) - (45° 00' 00")	5	32	51	35	(22) + (24)	75	28	43
4	OBSERVED ANGLE R_1	67	48	20		23	LOG TAN (22)	8	987	3238	TO LOCATE STATION O				
5	(2) + (4) [ENTER ON THIS LINE]	179	59	60		24	LOG TAN (11)	9	935	4612	26	LOG GRID DISTANCE A TO B (FROM AUX COMP DN REV)	3	479	5672
6	(180° / 2200") - (5) = ANGLE A_2	30	40	40		25	(22) + (24)	8	922	7850	37	LOG SIN (35)	9	985	8996
7	OBSERVED ANGLE O_2	58	58	40		26	REPEAT (11)	40	45	30	38	(36) + (37)	3	465	4668
8	REPEAT (2)	81	31	00		27	ANGLE HAVING LOG TAN (25)	4	47	07	29	REPEAT (12)	9	932	9643
9	(7) + (8) [ENTER ON THIS LINE]	140	29	40		28	(26) - (27)	35	58	23	40	(38) - (29) = LOG GRID DISTANCE A TO O	3	532	5025
10	(180° / 2200") - (9) = ANGLE B_1	39	30	20		29	(28) + (27)	45	32	37	TO LOCATE STATION R				
11	1/2 OF (2)	40	45	30	30	REPEAT (28) OR (29), ANGLE A_1	45	32	37	41	LOG GRID DISTANCE A TO B (FROM AUX COMP DN REV)	3	479	5672	
12	LOG SIN (6)	9	707	7484	31	REPEAT (4)	30	40	40	42	LOG SIN (24)	9	768	9374	
13	LOG SIN (7)	9	932	9643	32	(30) + (23)	76	13	17	43	(41) + (42)	3	248	5046	
14	LOG SIN (2)	9	899	5797	33	(30) + (23)	76	13	17	44	REPEAT (18)	9	966	5675	
15	(12) + (13) + (14)	9	540	2924	34	(30) + (23)	76	13	17	45	(43) - (44) = LOG GRID DISTANCE A TO R	3	281	9371	
REAR STATION B CARLTON AZ A TO B (FROM REV) 46 42 25 STA ANGLE REPEAT (30) 45 32 37 SUM 92 15 02 360° / 6400" 92 15 02 AZIMUTH A TO O 92 15 02 (+) 180° / 2200" 180 00 00 AZIMUTH O TO A 272 15 02					TO LOCATE STATION Q STATION A GRUBER VERT A TO A WITH SIGN REVERSED 47 00 LOG TAN VERT 8 135 8510 REPEAT (40) 3 532 5025 LOG COS BEARING 8 594 0554 SUM LOG 3 532 1673 LOG SIN BEARING 9 999 6648 REPEAT (40) 3 532 5025 LOG COS BEARING 8 594 0554 SUM LOG 2 126 5579										
REAR STATION B CARLTON AZ A TO B (FROM REV) 46 42 25 STA ANGLE REPEAT (32) 76 13 17 SUM 122 55 42 360° / 6400" 122 55 42 AZIMUTH A TO R 122 55 42 (+) 180° / 2200" 180 00 00 AZIMUTH R TO A 302 55 42					TO LOCATE STATION R STATION A GRUBER VERT A TO A WITH SIGN REVERSED 01 32 00 LOG TAN VERT 8 427 6176 REPEAT (40) 3 281 9371 LOG COS BEARING 9 735 2711 SUM LOG 3 205 8808 LOG SIN BEARING 9 923 9437 REPEAT (40) 3 281 9371 LOG COS BEARING 9 735 2711 SUM LOG 3 017 2082										
* DIFFERENCE IN HEIGHTS OF TARGET AND INSTRUMENT FROM GUIDE ON REVERSE ** CORRECTION FOR CURVATURE AND REFRACTION FROM TABLE ON REVERSE					STATION R BILL COMPUTER Cpl Jones CHECKER Cpl Smith SHEET 1 OF 1 SHEETS										

DA FORM 6-18
1 APR 56

PREVIOUS EDITIONS OF THIS FORM ARE OBSOLETE. THIS FORM TOGETHER WITH
DA FORMS 6-2, 6-8 AND 6-19 REPLACES DA FORM 6-2a, 1 OCT 52, WHICH IS OBSOLETE.

Figure 117. Solution of two-point resection, fourth-order survey.

AUXILIARY COMPUTATION AZIMUTH AND DISTANCE FROM A TO B					
STATION	E COORDINATE		N COORDINATE		
FROM STATION A	A	541 835 .70	A	3 835 349 .00	
TO STATION B	B	544 031 .60	B	3 837 417 .80	
IF A IS LESS THAN B REPEAT A	AA	541 835 .70	AA	3 835 349 .00	
IF AA IS BLANK, USE A-B, SIGN- IF AA IS FILLED, USE B-AA, SIGN+	dE	2 195 .9	dN	2 068 .8	
LOG dE	3.341 6126		ANGLE HAVING LOG TAN BEARING A TO B		46 42 25
LOG dN	3.315 7185		DETERMINE AZIMUTH FROM BEARING BY PLOTTING dE AND dN ON SKETCH AS GUIDE		
LOG dE - LOG dN = LOG TAN BEARING A TO B	0.025 8941		AZIMUTH A TO B [ENTER DN FRONT]		46 42 25
IF dE IS MORE THAN dN			IF dE IS LESS THAN dN		
REPEAT LOG dE	3.341 6126		REPEAT LOG dN		
LOG SIN BEARING A TO B	9.862 0454		LOG COS BEARING A TO B		
LOG dE - LOG SIN BEARING = LOG GRID DISTANCE A TO B	3.479 5672		LOG dN - LOG COS BEARING = LOG GRID DISTANCE A TO B		
[ENTER LOG GRID DISTANCE A TO B IN (34) AND/OR (41) DN FRONT]					

TABLE - CORRECTION FOR CURVATURE AND REFRACTION
(NO INTERPOLATION NECESSARY FOR ARTILLERY SURVEY)

(SIGN ALWAYS MINUS)			
Log Side (M)	Corr (M)	Log Side (M)	Corr (M)
3.079	.1	3.712	1.8
3.230	.2	3.736	2.0
3.322	.3	3.784	2.5
3.386	.4	3.824	3.0
3.435	.5	3.857	3.5
3.473	.6	3.886	4.0
3.508	.7	3.912	4.5
3.537	.8	3.934	5.0
3.562	.9	3.955	5.5
3.584	1.0	3.974	6.0
3.625	1.2	3.992	6.5
3.658	1.4	4.007	7.0
3.687	1.6		

GIVEN:

Coordinates of stations A and B.
Height of station A.

FIELD DATA:

Observe horizontal angles Q_1 , Q_2 , R_1 , and R_2 .
Observe vertical angle(s) from station(s) Q or (and) R to station A.
Measure height(s) of instrument(s) at station(s) Q or (and) R to nearest 0.1 meter.
Estimate height of target at station A, if not known.

GUIDE:

Enter observed field data in blocks marked .
Find difference(s) between heights of instrument(s) and target as follows:

	STATION Q	STATION R
a Known or Estimated Height of Target	+ 4 0	+ 4 0
b Measured Height(s) of Instrument	- 1 6	- 1 6
c Algebraic Sum a and b [Enter, with sign, in block(s) marked *]	⊕ - 2 4	⊕ - 2 4

Enter correction(s) for curvature and refraction in block(s) marked * *.

LIMITATIONS:

Angles A_1 , A_2 , B_1 , B_2 , Q_1 , Q_2 , R_1 , and R_2 should be greater than $22\frac{1}{2}^\circ$ ($400m$) or accuracy may fall below specifications

RESULTS:

Coordinates and height(s) of station(s) Q or (and) R.
Azimuth(s) from station(s) Q or (and) R to station A.

FORMULAS:

$$A_1 + B_2 = Q_1 + R_2$$

$$\tan Z = \frac{\sin A_2 \sin Q_2 \sin R_2}{\sin B_1 \sin Q_1 \sin R_1} \quad \text{or} \quad \tan Z = \frac{\sin B_1 \sin Q_1 \sin R_1}{\sin A_2 \sin Q_2 \sin R_2}$$

$$\tan \frac{1}{2}(A_1 - B_2) = \tan \frac{1}{2}(A_1 + B_2) \tan(Z - 45^\circ) \quad \tan \frac{1}{2}(B_2 - A_1) = \tan \frac{1}{2}(A_1 + B_2) \tan(Z - 45^\circ)$$

$$AQ = \frac{AB \sin(B_1 + B_2)}{\sin Q_2}$$

$$AR = \frac{AB \sin B_2}{\sin R_1}$$

Z = an auxiliary angle required only in the computations (always between 45 and 90 degrees).

Figure 118. Back of DA Form 6-18.

Section VI. INTERSECTION

264. General

Intersection is the method of triangulation in which only two angles in a triangle are measured. The third angle is determined by subtracting the sum of the two measured angles from 180° (3,200 mils).

265. Specifications

See appendix II for specifications and techniques in triangulation.

266. Limitations

a. As in triangulation, no distance angle in the triangle should be less than $22\frac{1}{2}^\circ$ (400 mils) or greater than $157\frac{1}{2}^\circ$ (2,800 mils); an angle between 30° (533 mils) and 150° (2,667 mils) is preferred. The only exception to this is when intersection is used in target area sur-

vey and then the apex angle should not be less than 150 mils and preferably should be at least 300 mils.

b. The accuracy of location of a point established by intersection is considered to be the same as the accuracy with which the points that established the base are located. However, survey can be extended from a point located by intersection only if that survey is of a lower accuracy than that of the intersected point.

267. Intersection Computations

Intersection computations are the same as those for triangulation except that, on the DA Form 6-8, the unmeasured angle must be computed and the angles in the triangle are not adjusted.

Section VII. TRILATERATION

268. General

When optical intervisibility between points and the need to extend control rapidly over relatively long distances precludes the use of some other method of survey, trilateration may be used. Trilateration is a method of survey through which control is extended by measuring the lengths of the sides of a triangle and computing the interior angles of the triangle from these lengths. The measurements are made using the tellurometer. This provides an accurate and rapid means of determining the lengths of the sides, thereby insuring determination of angles which will permit the extension of control to fourth- and fifth-order accuracies.

269. DA Form 6-7a

a. DA Form 6-7a is used for the computation of the trilateration problem (fig. 119).

b. Entries required for the form are the UTM grid or sea level distances for the sides of the triangle. The longest side is always placed in block 1 of the form.

c. The formulas to be used as shown on the back of the form.

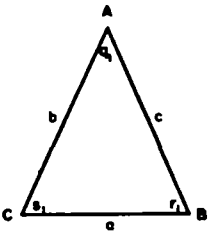
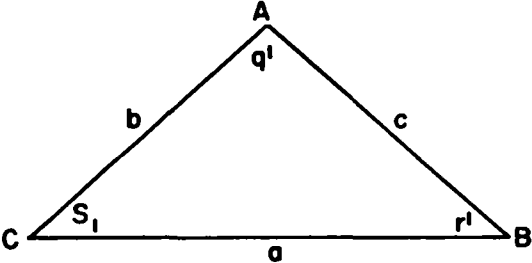
d. After the angles have been computed, they can be used in conjunction with the side lengths to extend coordinate control, provided a known direction is available. If sea level distances were used on DA Form 6-7a, they must be converted to UTM grid distance when the coordinates are computed on DA Form 6-2. The log scale factor is used for this conversion.

270. Limitations of Trilateration

a. Due to increased lengths of the sides and lack of optical intervisibility in some cases, direction must be provided at points within the scheme by some means other than trilateration. This direction is carried through the computations but some means must be used to place the direction on the ground where it can be used.

b. For best results, trilateration schemes should be planned so that distance angles, when computed, exceed $22\frac{1}{2}^\circ$ (400 mils) and, preferably, exceed 30° (533 mils).

c. Extensive map and ground reconnaissance are required to insure sites with electrical line-of-sight capabilities and to insure that minimum distance angle requirements can be met from selected positions.

COMPUTATION - PLANE TRIANGLE (Using Three Sides)			
	REQUIRED DATA* UTM grid lines a, b, and c. OPTIONAL DATA Plane UTM grid azimuth line a, b, or c. KNOWN AZIMUTH TO _____ = _____ Plane UTM grid coordinates station A, B, or C. KNOWN COORDINATES E _____ Sta. _____ N _____	SKETCH: 	
1 KNOWN LENGTH a = 91 27 07 2 KNOWN LENGTH b = 61 07 25 3 KNOWN LENGTH c = 89 73 53 4 (1) + (2) + (3) = 242 07 85 5 $\frac{1}{2}$ OF (4) = 121 03 92 6 (1) = 91 27 07 7 (5) - (6) = 29 76 85 8 LOG (7) = 3 473 7570 9 LOG (5) = 4 082 9260 10 (8) + (9) = 7 556 6830 11 LOG (2) = 3 785 8457 12 (10) - (11) = 3 770 8373 13 LOG (3) = 3 952 9633 14 (12) - (13) = 9 817 8740 15 10.000 0000 + (14) = 9 817 8740 16 $\frac{1}{2}$ OF (15) = 9 908 9370 17 ANGLE HAVING LOG COS (16) = 35° 49' 18" 18 2 X (17) = 71° 38' 36"			
NOTE: Always use a as longest known side. 19 (11) = 3 785 8457 20 LOG SIN (18) = 9 977 3186 21 (19) + (20) = 3 763 1643 22 LOG (1) = 3 960 3314 23 (21) - (22) = 9 802 8329 24 ANGLE HAVING LOG SIN (23) = r_1 = 39° 25' 35" 25 (13) = 3 952 9633 26 (20) = 9 977 3186 27 (25) + (26) = 3 930 2819 28 (22) = 3 960 3314 29 (27) - (28) = 9 969 9505 30 ANGLE HAVING LOG SIN (29) = s_1 = 68° 55' 51"			
PARTIAL PROOF			
31 (18) = 71° 38' 36" 32 (24) = 39° 25' 35" 33 (30) = 68° 55' 51" 34 (31) + (32) + (33) = $\frac{180^\circ}{3200\text{m}}$ = 180° 00' 02"			
REMARKS * Sea level distance lines a, b, and c.			
COMPUTER	CHECKER	DATE	

DA FORM 6-7a
1 OCT 52

Figure 119. Solution of trilateration problem, fourth-order survey.

PART FOUR
ARTILLERY SURVEY OPERATIONS AND PLANNING
CHAPTER 16
FIELD ARTILLERY BATTALION AND BATTERY SURVEY OPERATIONS

Section I. GENERAL

271. General

a. Paragraphs 272 through 282 cover survey operations for all field artillery battalions and batteries which have survey requirements, except field artillery target acquisition battalions and batteries. Survey operations for field artillery target acquisition units are discussed in chapter 18.

b. Survey operations are performed by survey personnel in the field artillery battalions for the purpose of obtaining the horizontal and vertical locations of points to be used in determining firing data and for providing a means of orienting pieces, instruments, radars, and searchlights. Survey operations of separate or detached batteries are performed for the same purpose.

272. Battalion Survey Control

a. Battalion installations must be located with respect to a common grid to permit massing of the fires of two or more battalions. This grid should be the grid of the next higher echelon whenever survey control points on that grid are available or when it is desired to mass the fires of more than one battalion.

b. A battalion survey control point (BnSCP) is a point provided by a higher survey echelon for the purpose of furnishing survey control to the battalion. More than one such point may be provided for a battalion.

273. Survey Control Points on Grid of Next Higher Echelon

a. Survey control points on the grid of the

next higher echelon may be available in the form of—

- (1) One or more trig points in the vicinity of the battalion installations. When available, trig points should be used as the basis for battalion survey operations if survey control points have not been established for the battalion by the next higher echelon.
- (2) One or more survey control points which have been established by the next higher echelon in the vicinity of the battalion installations. These survey control points should be used as the basis for battalion survey operations.

b. After he has verified that the battalion survey data contains no error, the battalion survey officer should report to his commander and the survey officer of the next higher echelon any differences which may exist between the battalion survey data and the data provided by the next higher echelon.

274. Use of Assumed Data

When neither survey control points nor trig points exist in the vicinity of the battalion (battery) installations, the battalion (battery) survey officer must establish a point and assume data for that point. This point (and its assumed data) establishes the battalion (battery) grid and is used as the basis for the battalion (battery) survey operations. When the next higher echelon establishes control in the battalion (battery) area, the assumed data must be converted to that control.

275. Converting to Grid of Next Higher Echelon

a. When data for the point used as a basis for the battalion (battery) survey operations differ from the data for that point furnished later by the next higher echelon, survey data determined by the battalion (battery) will normally be converted to the grid of the next higher echelon. The methods of converting survey data are described in chapter 26. Unless the tactical situation causes the commander to decide otherwise, battalion (battery) data are converted when data differ by—

- (1) Two mils or more in azimuth.
- (2) Ten meters or more in radial error.
- (3) Two meters or more in height.

b. If the next higher echelon should convert its survey control to a different grid, the battalion must also convert to that grid.

276. Use of Survey Methods

Field artillery battalion survey operations may be performed by using any or all of the artillery survey methods, provided the limitations of the selected survey methods are not exceeded. A comparison of the different methods is shown below.

a. *Traverse.* For most artillery survey operations, traverse is the best method to use because of its simplicity, speed, flexibility, and accuracy when performed over open terrain for comparatively short distances. In heavily wooded or rough terrain, the expenditure of time in performing a traverse is extensive.

b. *Triangulation.* Triangulation should be used in mountainous terrain where taping is difficult or impossible and in rough terrain that would require an extensive expenditure of time to traverse. In gentle rolling or flat, treeless terrain, triangulation should be used when a large area is to be surveyed. In such terrain, traverse is faster unless distances between stations exceed 1,500 to 2,000 meters. Where distances are large, triangulation will save time and personnel. However, more extensive reconnaissance is required for triangulation than for traverse. Distance and angle measurements to achieve any given accuracy when triangulation is used must be more accurate than for traverse.

c. *Intersection.* Locating the position of a point by using the intersection method is relatively simple and speedy. However, the method depends on intervisibility between the ends of the base line and the unknown point. Intersection must be used to locate points beyond friendly front lines. When practicable, these locations should be checked by intersection from more than one base.

d. *Resection.* The resection method of locating a point requires very little fieldwork. Resection normally is used in artillery battalion survey to establish a survey control point or observation post(s) in areas where the only existing control is on points which are inaccessible. It is used for improvement over map-spotted or assumed data. However, any location determined by resection must be checked by a separate determination (preferably traverse or triangulation) at the first opportunity.

277. Use of Astronomic Observation

The problem of converting data to a common grid is greatly simplified if survey personnel use correct grid azimuth to initiate survey operations. Correct grid azimuth can be obtained by astronomic observation. Battalion survey personnel should be trained in the determination of grid azimuth by observation of the sun and stars using the altitude method and observation of Polaris using the hour-angle method. They should also be trained in the transmission of direction by simultaneous observations.

278. Division of Battalion and Battery Survey Operations

a. The survey operations of a field artillery battalion (separate or detached battery) consist of one or more of the following:

- (1) Position area survey.
- (2) Connection survey.
- (3) Target area survey.

b. The survey operations performed by a field artillery battalion or a separate or detached field artillery battery depend mainly on three factors, as follows:

- (1) The type of unit (including assignment and mission).

- (2) The availability of survey control.
- (3) The amount of time available in which to perform initial survey operations.

279. Sequence of Battalion (Battery) Survey Operations

Battalion (battery) survey operations are performed in the sequence listed below.

a. Planning (Which Includes Reconnaissance). A general discussion of survey planning is contained in chapter 20. *In order to insure maximum effectiveness, battalion (battery) survey operations should be planned and initiated prior to the occupation of position, whenever possible.*

b. Fieldwork. Fieldwork consists of establishing survey stations and measuring angles and distances necessary to determine required survey data. The assignment of personnel to accomplish the required fieldwork is determined by the number of surveying parties available and the unit SOP.

c. Computations. Each survey computation must be performed by two computers working independently and, when possible, checked with a slide rule by the chief of party. Whenever possible, survey computations should be performed concurrently with the determination of field data. *This will insure that errors are detected and corrected at the earliest possible time and will facilitate the early use of a surveyed firing chart.*

d. Plotting. After the survey data have been determined, battalion survey personnel may be required to prepare the firing chart (FM 6-40).

280. Survey Operations of Searchlight Batteries

When suitable maps are not available, survey operations are performed by personnel of searchlight batteries for the purpose of determining survey data from which light direction personnel can determine orienting data for the searchlights. The survey operations which must be performed are those necessary to establish the grid coordinates and height of each searchlight. If desired, a grid azimuth for orientation of the searchlights may be estab-

lished and furnished to searchlight battery personnel.

281. Survey of Alternate Positions

Survey operations for alternate positions should be performed as soon as survey operations are completed for primary positions. The survey requirements for alternate positions are identical to the requirements for primary positions.

282. Limited Time Survey

Battalion (battery) survey personnel must provide the best firing chart and the best means of orienting weapons in the time available. When time is a consideration, the survey officer must plan and accomplish the survey operations necessary to furnish the fire direction officer with an improved firing chart. The extent of the survey conducted and the methods employed will depend primarily on the time available. The procedures used for accomplishing the division of operations may be any combination of the following:

a. Position Area.

- (1) Map-spot battery centers (lay by compass).
- (2) Map-spot battery centers and establish orienting lines by directional traverse or simultaneous observation.
- (3) Map-spot battalion SCP, locate battery centers, and establish orienting lines by open traverse from designated battalion SCP.

b. Connection Survey.

- (1) Use map for connection survey.
- (2) Establish survey by firing.
- (3) Employ simultaneous observation or directional traverse from battalion SCP to 01 or target area survey control point (TASCP).

c. Target Area Survey.

- (1) Map-spot both 01 and 02.
- (2) Map-spot TASCP and short traverse to locate 01 and 02.
- (3) Map-spot TASCP and locate 01 and 02 by intersection from an auxiliary base.
- (4) Map-spot critical points.

Section II. POSITION AREA SURVEY

283. General

a. Survey control is required in the position area of each firing battery of the field artillery battalion (both cannon and missile) and in the position area of the mortar platoon of the combat support company of the battle group. Position area survey is performed by battalion (separate or detached battery) survey personnel for the purpose of—

- (1) Locating weapons positions and radars.
- (2) Providing means for orienting weapons and radars.
- (3) Determining orienting angles for each firing battery.

b. The position area surveys for field artillery cannon and missile units are performed to a minimum prescribed accuracy of fifth order (1:1,000). When the TOE of the unit authorizes the aiming circle M2 as the instrument for position survey (separate batteries, mortar platoons), the survey is performed to a minimum prescribed accuracy of 1:500.

284. Terms Used in Conjunction With Position Area Survey

The following terms are used in conjunction with position area survey:

a. *Battery Center*. A point materialized on the ground at the approximate geometric center of the weapons position. The battery center is the chart location of the battery (FM 6-40). (The location of the battery center is designated by the battery commander or battery executive. The survey officer may select a tentative battery center if the battalion (battery) SOP so states.)

b. *Orienting Line (OL)*. A line of known direction materialized on the ground near the firing battery, which serves as a basis for laying for direction (FM 6-40). (The azimuth of the orienting line is included in the data reported to the fire direction center.)

c. *Orienting Station*. A point on the orienting line, established on the ground, at which the battery executive sets up an aiming circle to lay the pieces (FM 6-40). (The location of the orienting station is designated by the battery commander or battery executive. The sur-

vey officer may select the location of the orienting station if the battalion (battery) SOP so states.)

d. *Registration point*. A point in the target area the location of which is known on the ground and on the firing chart (FM 6-40).

e. *Orienting angle*. The horizontal, clockwise angle from the line of fire to the orienting line or the orienting line extended: it is never greater than 3,200 mils (FM 6-40). (The orienting angle determined by survey personnel is computed by subtracting the azimuth of the desired line of fire from the azimuth of the orienting line, adding 6,400 mils if necessary. For very heavy artillery, a similar angle is determined for each piece.)

f. *Radar orienting point*. A point which is used to orient the radar. The radar orienting point for field artillery radar sets is established in a direction as nearly in the center of sector of search of the radar as possible. (The radar officer furnishes to the survey officer the approximate azimuth on which the radar orienting point should be established.)

285. Method of Performing Position Area Survey

a. Except when time is limited, a closed traverse is used to perform the position area survey. The position area survey is initiated at a survey control point, the point that establishes the unit grid, or a station established by the connection survey. The survey is closed on the starting point or on a station established to an accuracy equal to or higher than that of the survey being performed.

b. If a terrain obstacle, such as a wide stream, prevents the use of a closed traverse throughout the entire position area, triangulation must be used to cross the obstacle. However, the number of triangles used should be kept to the minimum.

286. Survey for Weapons Positions

a. In surveying a weapons position, an orienting station is established near the battery center. Normally, this point is used as one end of the orienting line, and the traverse leg used to establish the station is used as the orienting line; this keeps the orienting line in

the closed traverse and reduces the chance of an error in the azimuth of the orienting line. If a traverse leg cannot be used as the orienting line, a prominent terrain object at least 300 meters away should be used. The azimuth of this line is determined by measuring the angle from the last traverse station to the selected point at the orienting station. In all cases for night operations, the orienting line must be prepared for orientation of the weapons at night; this is accomplished by placing a stake equipped with a night lighting device on the orienting line approximately 100 meters from the orienting station. (When an intermediate point cannot be established on the orienting line, an alternate orienting line is established on which the night orienting point can be set up.)

b. The coordinates and height of the battery center are determined by establishing a traverse station or an offset (an open traverse leg) from the orienting station to the battery center. (For very heavy artillery and missile units, the coordinates and height of each piece or launcher are determined by an offset from the orienting station.)

287. Survey for Radar

If the radar is not in position at the time the survey is performed, either the stake marking the radar position or the stake marking the radar orienting point is used as a traverse station (1 and 2, fig. 120). If the radar is in position at the time of the survey, the stake marking the radar orienting point is used as a traverse station (3, fig. 120) or as a directional traverse station (4, fig. 120). (If the radar is in position, horizontal and vertical angles for the radar are measured to the telescope on the radar parabola.)

a. The orienting azimuth for the radar can be determined in one of two ways—by measuring, at the radar position stake, the horizontal angle for the rear traverse station to the orienting point stake (1, fig. 120) or by measuring, at the orienting point stake, the horizontal angle from the rear traverse station to the radar position stake (2, fig. 120) or to the radar telescope (3 and 4, fig. 120). If the azimuth is determined at the orienting point stake, 3,200 mils must be added to, or subtracted from, the

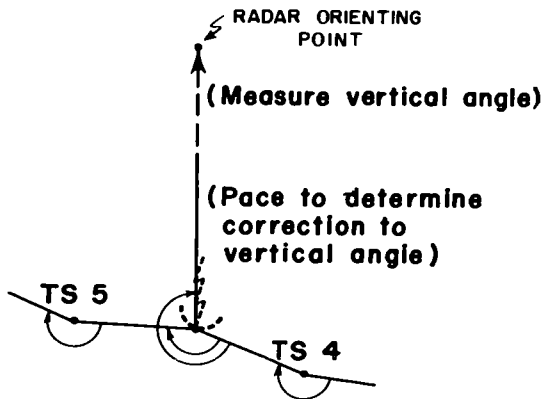
determined azimuth to obtain the azimuth from the radar to the orienting point stake.

b. The vertical angle for the radar can be determined in one of two ways—by measuring, at the radar position stake, the vertical angle to the orienting point stake (1, fig. 120) or by measuring, at the orienting point stake, the vertical angle to the radar position stake (2, fig. 120) or the radar telescope (3 and 4, fig. 120). (If the vertical angle is measured at the orienting point stake, the vertical angle at the radar will be opposite in sign to the measured angle.) If the vertical angle is measured to a stake, it must be corrected for the height of the radar telescope about the ground. (This correction can be determined by the mil formula; i.e., by dividing the height above the ground of the radar telescope (in meters) by the taped or paced distance between the radar position stake and the radar orienting point stake (in thousands of meters).) If the vertical angle is measured to the radar telescope, it is not necessary to determine a correction for the vertical angle. The telescope on the radar antenna and the survey instrument are pointed at each other. The vertical angle measured by the survey instrument (with the sign changed) is set on the vertical angle scale of the radar. The vertical angle to the orienting stake is then measured with the radar.

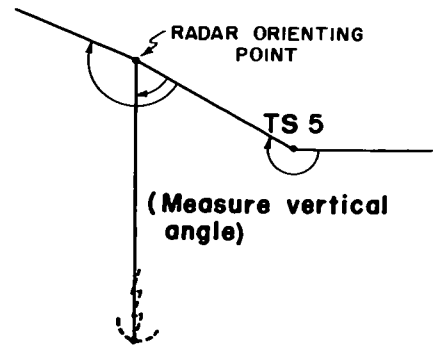
c. The coordinates and the ground height of the radar are determined from the traverse data (1, fig. 120) or by establishing an offset (2, 3, and 4, fig. 120). The vertical angle used to determine the ground height of the radar is measured to the height of instrument regardless of the manner by which the vertical angle for the radar is determined. (If the vertical angle for the radar is determined by measuring to the radar telescope and the radar location is determined by an offset from the radar orienting point (3, fig. 120), a vertical angle to the height of instrument must also be measured.) The vertical angle to the height of instrument is used to compute the ground height of the radar. *The height of the radar parabola is then determined by adding to the computed ground height of the radar the vertical distance in meters (measured with a tape to the nearest 0.1 of a meter) from the ground to the center of the radar parabola.*

d. If the theodolite is used to perform the

①

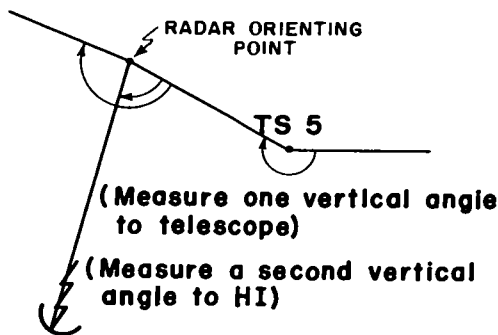


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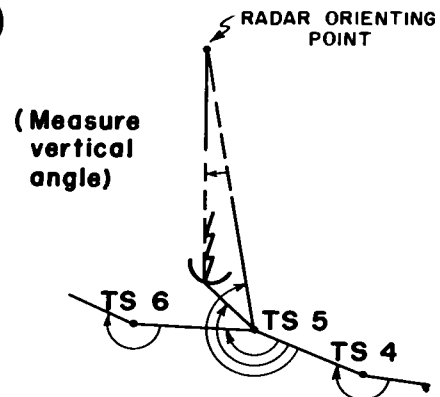


RADAR NOT IN POSITION

③



④



RADAR IN POSITION

**SOLID LINES INDICATE DISTANCES DETERMINED BY TAPING
ARCS WITH ARROWS INDICATE MEASURED ANGLES**

Figure 120. Locating and orienting a radar.

position area survey, the radar (or radar position stake) can be located by intersection (or triangulation). In this case, the radar orienting point is established and is used as a traverse station. The orienting point is also used as one end of an intersection (triangulation) base.

The next traverse station is used as the other end of the base. *The base is double-taped to a comparative accuracy of 1:3,000 either by two taping teams or by one taping team taping the base twice. The radar is located and oriented as discussed in a through c above.*

Section III. CONNECTION SURVEY

288. General

a. Connection survey is that part of the survey operations performed by battalion (separate battery) survey personnel for the purpose of locating the target area survey and the position area survey on a common grid.

b. Connection surveys are performed to a prescribed accuracy of fifth order.

289. Methods of Performing Connection Survey

a. A closed traverse normally is used to perform the connection survey although triangulation or intersection can be used when the terrain is unsuitable for traverse. The connection survey locates one or more of the target area base observation posts or it may establish a target area survey control point from which target area base survey operations are initiated by another survey party. The connection survey is initiated at a battalion SCP or the point that establishes the battalion grid. When the connection survey is initiated at a battalion SCP, it may close on the battalion SCP or on

any other survey control point established to an accuracy of 1:1,000 on the same grid as the battalion SCP. When the connection survey is initiated at the point that establishes the battalion grid (i.e., when data for the starting point is assumed), it must close on the starting point. (This point does not become the battalion SCP unless survey control for the point is established by the next higher echelon of survey.)

b. The survey party performing the connection survey must locate at least one observation post (designated 01) of the target area base or a target area survey control point (TASCP). The coordinates, the height, and an azimuth from which the azimuth of the bases may be determined for the target area observation post(s) are furnished to the survey party performing the target area survey.

c. In many cases, heavy or very heavy artillery units need no connection survey. If target area survey operations are to be performed, the control is obtained from that control which is based on the same grid established by a light or medium unit.

Section IV. TARGET AREA SURVEY

290. General

a. Target area survey is that part of the survey operations performed by battalion (detached battery) survey personnel for the purpose of establishing the target area base and locating critical points in the target area; i.e., registration point(s) and restitution points.

b. Critical points are surveyed to *minimum* prescribed accuracies of 1:500.

c. The target area base when established by the target area survey party is surveyed to a *minimum* accuracy of fifth order.

291. Terms Used in Conjunction With Target Area Survey

a. *Target Area Base*. A target area base consists of two or more observation posts which are used to locate the critical points in the target area and/or targets of opportunity and to conduct center-of-impact and high-burst

registrations. (When there are more than two observation posts, any two of them form an intersection base. The controlling observation post is designated 01, whether it is on the right or left end of the target area base; the auxiliary observation posts are designated 02, 03, etc. (FM 6-40).)

b. *Azimuth Mark for Target Area Observation Post*. An azimuth mark which is used to orient the instrument is established at the target area base for each observation post. The azimuth to the azimuth mark may be determined by using the back-azimuth of a traverse or intersection leg used to locate the observation post, by computing the direction to some well-defined known point, or by using the adjacent observation post (where OP's are intervisible). An auxiliary or intermediate orienting point should be established for night operations.

292. Selection of Observation Posts

a. Initially, two or more observation posts are selected at points from which the critical points in the target area are visible. If possible, the distance between any two observation posts should be sufficient to insure a minimum angle of intersection at any of the critical points of 300 mils (aiming circle). These minimum angles at the critical points in the target area are necessary to insure results that approach the accuracies prescribed for target area survey. If the observation posts of the target area base cannot be located sufficiently far apart to provide a minimum angle or intersection of 300 mils, they should be located as far apart as possible. *In any case, the distance between observation posts that are used as the ends of an intersection base must be sufficient to provide a minimum angle of intersection of 150 mils (aiming circle) at any critical point in the*

target area. (The consistent accuracy that can be obtained from the location of points with angles of this minimum size is approximately 1:200.)

b. The location of each critical point should be checked from at least two intersection bases. As soon as possible, additional observation posts should be selected to provide this check. In addition to providing the check, observation posts should provide observation in the unit's zone of action, especially of those areas which are not visible from the observation posts originally selected.

293. Methods of Performing Target Area Base Survey

a. The method of survey normally used by the survey party in the field artillery battalion to perform the target area base survey is a closed traverse, or when the terrain allows and the enemy situation is such that traversing to

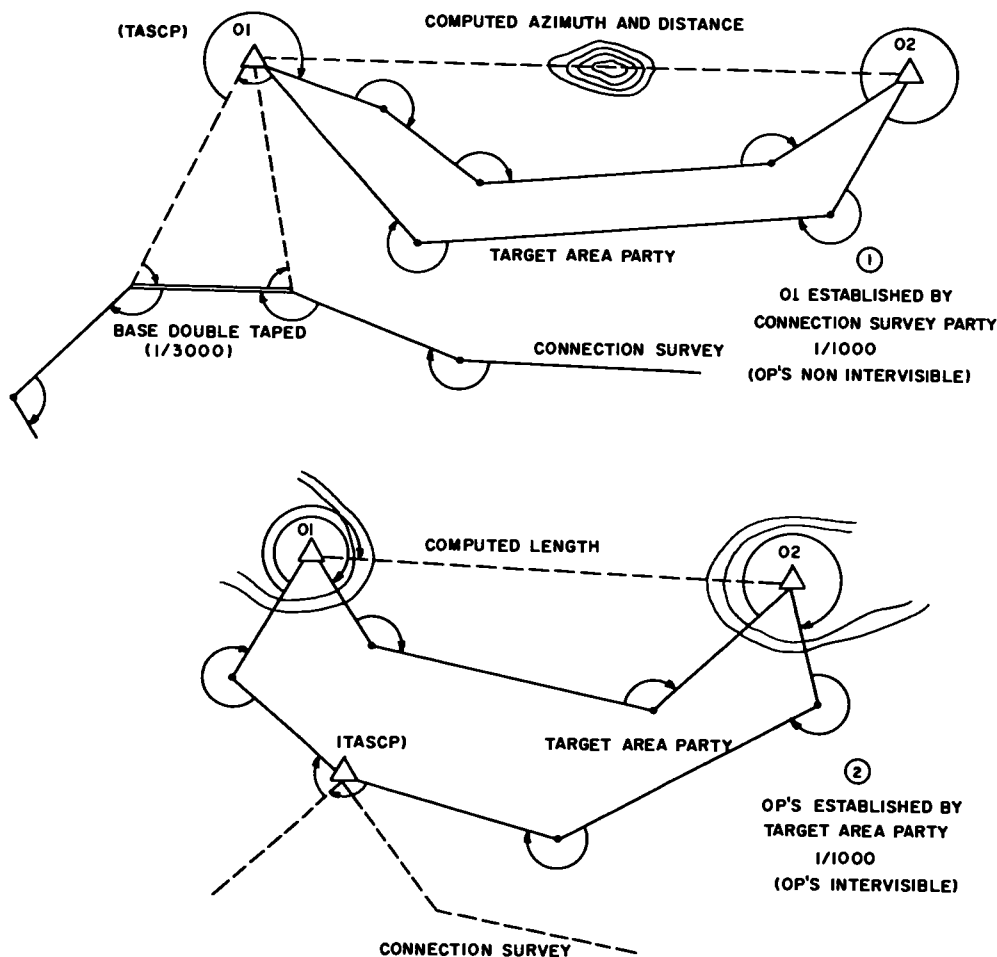


Figure 121. Target area base survey.

an OP would disclose its position, triangulation is used. On some occasions it may be necessary to locate the OP by intersection or offset from a traverse station in the vicinity of the OP. The OP's are located to an accuracy of fifth order.

b. In issuing the survey order, the survey officer will designate which of the survey parties is to perform the target area base survey. The specific location of both OP's may also be designated or an approximate location given and specific location left to the discretion of the chief surveyor or chief of party. The location of a target area survey control point will be given; or, if one OP is located as part of the connection survey, it may be designated as the target area survey control point.

c. The observation posts are designated 01 and 02. 01 is considered the control OP and is plotted on the firing chart. 01 may be the OP on the right or left. 01 is always that OP requiring the least amount of fieldwork to establish its location. Less directional accuracy will be lost through angular measurements when the fieldwork and the number of main scheme angles are held to a minimum. Examples of target area base surveys are shown in figure 121.

294. Method of Performing Target Area Survey

a. Intersection must be used to perform the target area survey. The length of each intersection base of the target area base is obtained by computation from the coordinates of the two observation posts that establish the base. If the observation posts are intervisible, the azimuth of the base is determined by measuring the horizontal angle at an observation post from the rear station to the observation post at the other end of the base. If the observation posts are not intervisible, the azimuth of the base is determined by computation by using the coordinates of the ends of the base. (The length of the base may be determined by double-taping to a comparative accuracy of 1:3,000 when the base is located in an area not under direct observation of the enemy.)

b. If the observation posts are intervisible, the interior horizontal angles are measured (1, fig. 122). If they are not intervisible, the angles at the ends of the base must be deter-

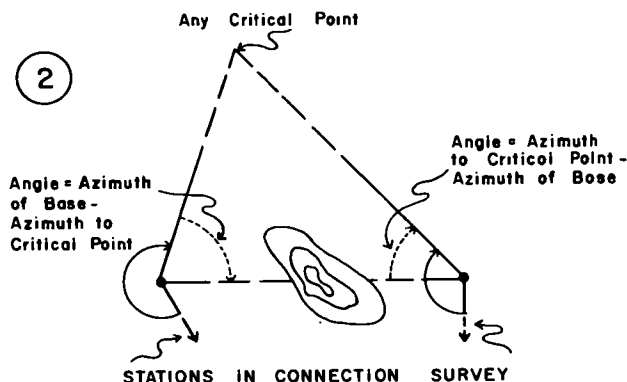
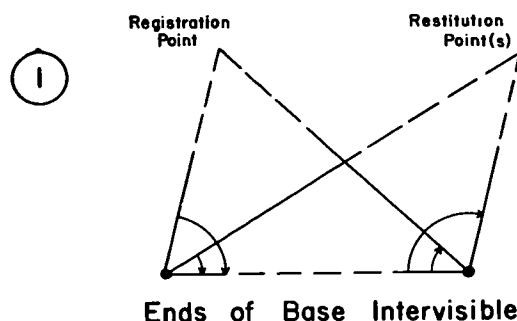


Figure 122. Target area survey.

mined by comparing the azimuth of the base with the azimuth from each observation post to the point being located (2, fig. 122). The azimuth of the line from each observation post is determined by measuring the horizontal angle at the observation post from the established azimuth mark (orienting station for night operations) to the point in the target area. When the critical point does not present a clearly defined vertical line and cannot be accurately bisected, the horizontal angles are measured by using a special technique of pointing. Pointings are made by placing the vertical line in the reticle on the right (left) edge of the object in measuring the first value of the angle and by placing the vertical line on the left (right) edge in measuring the second value of the angle. The mean angle obtained with this method must be verified by determining

at least one more mean angle by using the same technique. (When this technique is used to measure horizontal angles with an aiming circle, two sets of pointings are made. The accumulated value of one set (one pointing to each edge of the object) should agree with the accumulated value from the other set within 1 mil. The accumulated values of both sets are added together and divided by 4 to determine the mean angle to the nearest 0.1 mil.)

c. Vertical angles are measured to the lowest visible point on the object.

d. The distance from either end of the intersection base to each critical point is computed by using the base length determined in *a* above and the angles determined by direct

measurement (1, fig. 122) or by comparison of azimuths (2, fig. 122). The coordinates and height of each point are determined in the same manner in which they are determined by triangulation.

e. The party performing the target area survey furnishes the location of the registration point(s) to the party performing the position area survey for computation of the orienting angle(s).

f. The locations of critical points determined from the target area base should be checked by establishing a second intersection base. (A second intersection base can be established by using a third observation post and either of the two observation posts used originally.)

CHAPTER 17

DIVISION ARTILLERY SURVEY

295. General

a. Survey operations are performed by survey personnel of division artillery headquarters battery for the purpose of placing the field artillery units organic, assigned, or attached to the division on a common grid.

b. Division artillery surveys are executed to a prescribed accuracy of fourth order (1:3,000). Specifications and techniques for fourth-order survey are found in appendix II.

296. Division Artillery Survey Personnel

A survey officer is assigned to the division artillery staff. The division artillery survey officer plans and supervises the division artillery survey operations. He advises the commander and appropriate staff officers on matters pertaining to survey. He coordinates the survey operations of the field artillery battalions (separate batteries) within the division.

297. Division Artillery Survey Information Center

a. A file of survey information and a survey information map are maintained in the survey information center (SIC) at the division artillery headquarters. The survey information center file and map are located at the division artillery command post and may be located in the division artillery operations section.

b. The survey information map shows the locations of survey control points and trig points and the schemes of all surveys performed by the division artillery survey section. The file of survey information consists of the trig lists prepared and issued by the Corps of Engineers, the trig lists prepared by the field artillery target acquisition battalion, and data for each control point established by division artillery survey operations. The data for each

control point established by division artillery are recorded on DA Form 6-5 (Record—Survey Control Point) (figs. 123 and 124).

c. The division artillery survey officer should maintain close liaison with the corps artillery survey officer. By so doing, he can obtain data for survey control points which have been established by the target acquisition battalion in the division area. Use of these points can save time and can eliminate unnecessary duplication of survey operations. He can also obtain data for points established in the vicinity of the target area which can be used by the battalion survey parties in performing the target area surveys and the target area base surveys.

298. Division Artillery Survey Control

a. Division artillery battalions, batteries, and other division installations that require survey control should be located with respect to a common grid. This grid should be the corps grid whenever control points on that grid are available. Control points on the corps grid are normally available in the form of trig points and survey control points for which data are known with respect to the UTM (or universal polar stereographic (UPS)) grid for the area of operations.

b. When neither survey control points nor trig points are available in the division area, the division artillery survey officer establishes a point and assumes data for that point. This point (and its assumed data) establishes the division grid which is used as the basis for the division artillery survey operations. When the data for the point differ from the data for that point as established by the field artillery target acquisition battalion of corps artillery, survey data determined by the division artillery are converted to the corps grid. In the initial stages

of an operation, it is not necessary for division artillery to convert azimuth to the corps grid if it differs from azimuth provided by the target acquisition battalion by 1 minute (0.3 mil) or less. However, it should be converted as soon as it is practicable. In any case, coordinates and height should be converted to the corps grid if they differ from the data provided by the target acquisition battalion.

299. Division Artillery Survey Operations

a. Division artillery survey operations should provide the best determination of data at the earliest possible time. Any of the artillery survey methods may be used to perform the surveys. In areas where survey control points are not available in the vicinity of the battalion, common direction can be transmitted by simultaneous observations. (Division artillery survey personnel should be trained in the determination of grid azimuth by astronomic and simultaneous observations.)

b. In addition to providing survey control points for battalions and/or batteries, the division artillery survey officer may designate points for which battalion surveys should determine survey data in order to check the accuracy

of the surveys being performed by the battalions.

c. Normally, division artillery survey operations are performed by the division artillery survey section.

d. When the time available to perform division artillery survey is limited, the division artillery commander *may* direct battalions of the artillery with the division to assist the division artillery survey section in performing the surveys necessary to establish the division artillery grid after the survey operations of the battalion have been completed. *When this is necessary, the division artillery survey section should, at the first opportunity, reperform the portions of the survey performed by battalion survey sections.*

e. When a target acquisition battery is attached to a division artillery, the survey parties of the target acquisition battery may perform part of the division artillery survey operations. The division artillery survey officer, in conjunction with the target acquisition battery commander, plans and supervises the coordinated survey operations.

CHAPTER 18

CORPS ARTILLERY SURVEY

300. General

a. Corps artillery survey operations are performed by the field artillery target acquisition battalion assigned to each corps artillery headquarters. The battalion commander of the field artillery target acquisition battalion is the corps artillery survey officer. The target acquisition battalion survey officer is responsible to the battalion commander for planning and supervising the battalion survey operations.

b. Survey operations are performed by survey personnel in the field artillery target acquisition battalion for the purposes of placing the field artillery with the corps (and other units requiring survey control) on a common grid and of locating the target acquisition battalion installations (which include flash, sound, and radar installations). Also included in survey operations are the collection, evaluation, and dissemination of survey information for all surveys executed in the corps area to a prescribed accuracy of fourth-order or greater. Surveys performed by the target acquisition battalion are executed to a prescribed accuracy of fourth-order.

301. Survey Information Center

a. A corps survey information center is established and maintained by the survey information center (SIC) personnel of headquarters battery of the target acquisition battalion. It is usually located in the vicinity of the corps artillery fire direction center. The SIC is an agency for collecting, evaluating, and disseminating survey data. The dissemination is accomplished by preparing and distributing trig lists and by furnishing survey information to personnel of other units upon request. Unless directed otherwise by the battalion commander,

all survey information is disseminated only through the survey information center.

b. Files of all survey control (fourth-order or greater) existing in the corps area and files of tie-in points established in adjacent corps areas by the target acquisition battalions or division artilleries in those areas are maintained in the survey information center. These files consist of trig lists published by higher headquarters (including trig lists prepared by the Corps of Engineers), trig lists published by field artillery target acquisition battalions operating in the adjacent corps areas, and data for each survey control point established by the target acquisition battalion survey parties and by the parties of the division artillery headquarters with the corps. The data for each survey control point established by the target acquisition battalion and by division artillery headquarters are recorded on DA Form 6-5 (figs. 123 and 124).

c. An operations map is maintained in the survey information center. The operations map shows the locations of all existing trig points and survey control points and the schemes of completed surveys. Overlays to the map show the survey operations that are currently being performed by the survey personnel of the target acquisition battalion (and division artilleries with the corps). The overlays also show the tactical situation, the location of each installation of the target acquisition battalion, present and proposed artillery positions, and proposed survey plans.

d. In addition to performing the functions of the survey information center discussed in *a* through *c* above, survey information center personnel assist the survey operations of the target acquisition battalion by computing and

SURVEY CONTROL POINT		NAME OR DESIGNATION (SCP) BECK LOCATED BY BTRY B, 1st FATAB		EASTING 554 436 44		NORTHING 3 935 704 45		HEIGHT 359 6		FT M YD	
		NOTEBOOK REFERENCE BOOK NR 4									
AZIMUTH MARK		AREA Fort Sill DATE DONE 1 DEC 1960 DATE FILED 1 DEC 1960		DESCRIPTION (General and specific locations, type of mark, etc.) STATION IS 1-INCH HOLLOW PIPE IN CENTER OF 8-INCH SQUARE CONCRETE BLOCK; 5 METERS WEST AND 1 1/2 METERS SOUTH OF SOUTHWEST CORNER OF BLDG T3077; ON FT SILL MILITARY RESERVATION.							
		RECORDS FILED AT 1st INF DIV ARTY, SIG									
		HOW LOCATED HORIZONTAL ☒ TRIG LIST ☒ TRAVERSE ☐ TRIANGULATION ☐ MAP ☐ OTHER		TRIG LIST ALTIMETRIC TRIGONOMETRIC MAP ☒ OTHER		ACCURACY 1ST - ORDER 2D - ORDER 3D - ORDER 1/3000 OTHER					
AZIMUTH MARK		NAME OR DESIGNATION (A-MK) WATER TOWER		EASTING		NORTHING		HEIGHT		FT M YD	
		DISTANCE FROM SCP (Fe., M., etc.) ☐ MEASURED ☒ ESTIMATED 1200 METERS		DESCRIPTION (Specific location, type of mark, etc.) WATER TOWER IS LARGE STEEL WATER TOWER IN 2900 AREA ON FT SILL MILITARY RESERVATION. EXACT STATION IS RED LIGHT BULB ON TOP OF TOWER.							
		AZIMUTH FROM SCP 42 84 73									
		HOW DETERMINED ☐ TRIG LIST ☐ ANGLE TURNED ☐ MAP ☐ TRAVERSE ☒ ASTRONOMIC ☐ OTHER									
		OTHER AZ MKS VISIBLE FROM SCP									
		2 None									
		3									
		4									
		(Station and Azimuth Mark Descriptions Continued on Reverse Side)									

DA FORM 6-5
 1 OCT 55

REPLACES DA FORM 6-5, 1 OCT 52,
 WHICH WILL BE USED UNTIL EXHAUSTED.

RECORD - SURVEY CONTROL POINT

REPLACES DA FORM 6-5, 1 OCT 52,
WHICH WILL BE USED UNTIL EXHAUSTED.

Figure 123. Entries made on front of DA Form 6-5

- (1) Checks of field records and computations of field parties.
- (2) Adjustment of traverses.
- (3) Conversion of survey data to the corps grid when survey operations have been performed with assumed data.
- (4) Transformation of coordinates and grid azimuths.
- (5) Conversion of coordinates (geographic to grid and/or grid to geographic).

302. Field Artillery Target Acquisition Battalion Survey Personnel

mander and assisted by the battalion survey officer, he—

b. The battalion survey officer is assigned to the battalion staff. The battalion survey officer plans and supervises the battalion survey operations, advises the battalion commander and the staff on matters pertaining to survey, and performs the coordination of the survey operations of *all* field artillery units operating in the corps area. An assistant battalion sur-

the initial phase consist of those necessary to establish a survey control point for each division artillery and each corps artillery battalion (and other points as directed by the battalion commander) and those necessary to establish survey control for the installations that are organic to the target acquisition battalion that require survey control.

c. The survey operations conducted during the expansion phase consist of the surveys necessary to place survey control points within 1,500 to 2,000 meters of any possible artillery position in the corps area.

d. The battalion survey officer designates to each platoon commander locations where survey parties are to establish survey control points. These survey control points are *established* for later extension of control and for checking surveys.

e. Survey operations of the target acquisition battalion are continuous. The amount of survey performed by the target acquisition battalion in any area of operations depends on the length of time that the corps remains in the area. When the corps is moving rapidly, the target acquisition battalion may be able to perform only the initial phase survey operations. When the corps remains in one area for an extended period of time, the target acquisition battalion conducts extensive survey operations.

305. Use of Assumed Data

Whenever possible, survey platoons initiate survey operations at survey control points (or trig points). When adequate survey control points do not exist in the area of operations, one or more of the survey platoons must initiate survey operations, using assumed coordinates and height. When at least one survey control point exists in the area of operations, the surveys of the battalion are based on the grid established by the coordinates and height(s) of the survey control point(s). The surveys of the platoons that used assumed initial data are converted to the grid established by the survey control point(s). When no survey control points exist in the area, the battalion survey officer designates a point and furnishes assumed data for the point. (The assumed data should approximate the correct grid data as closely as possible.) The surveys of all of the platoons are then converted to the grid estab-

lished with the assumed point and the azimuth established at the assumed point.

306. Azimuths

Azimuths at all points of the battalion survey should be correct grid azimuths. Correct grid azimuth can normally be established by astronomic observation or by use of the gyro azimuth surveying instrument. When two intervisible survey control points (based on correct grid data) or trig points exist, correct grid azimuth can be obtained from these points. If the correct grid azimuth between the points is not known, it can be computed by using the grid coordinates of the points.

307. Survey Control Points

Survey parties of the battalion establish survey control points approximately every 1,500 to 2,000 meters along the routes of the surveys. A station of this type is established at each point for division artillery, for corps artillery battalions, and for those points from which target acquisition battery installations are located. The same type of station is also established at each point designated for later extension of control and for checking surveys. Each of these survey control points is marked by a hub and a reference stake. An azimuth for each survey control point is established either to an azimuth mark or to an adjacent survey control point. A description of each survey control point is prepared on DA Form 6-5 and forwarded to the survey information center for file.

308. Planning Target Acquisition Battery Survey Operations

The points for which survey control must be established by the survey platoon of each target acquisition battery fall into two general categories—those for installations of the target acquisition battalion and those for installations of other units. The commander of the target acquisition battery survey platoon plans the initial phase operations of the platoon by first considering the operations necessary to locate the target acquisition battalion installations. He then modifies this plan, as necessary, to provide survey control for the installations of other units. If priorities have been established by the battalion survey officer, the platoon

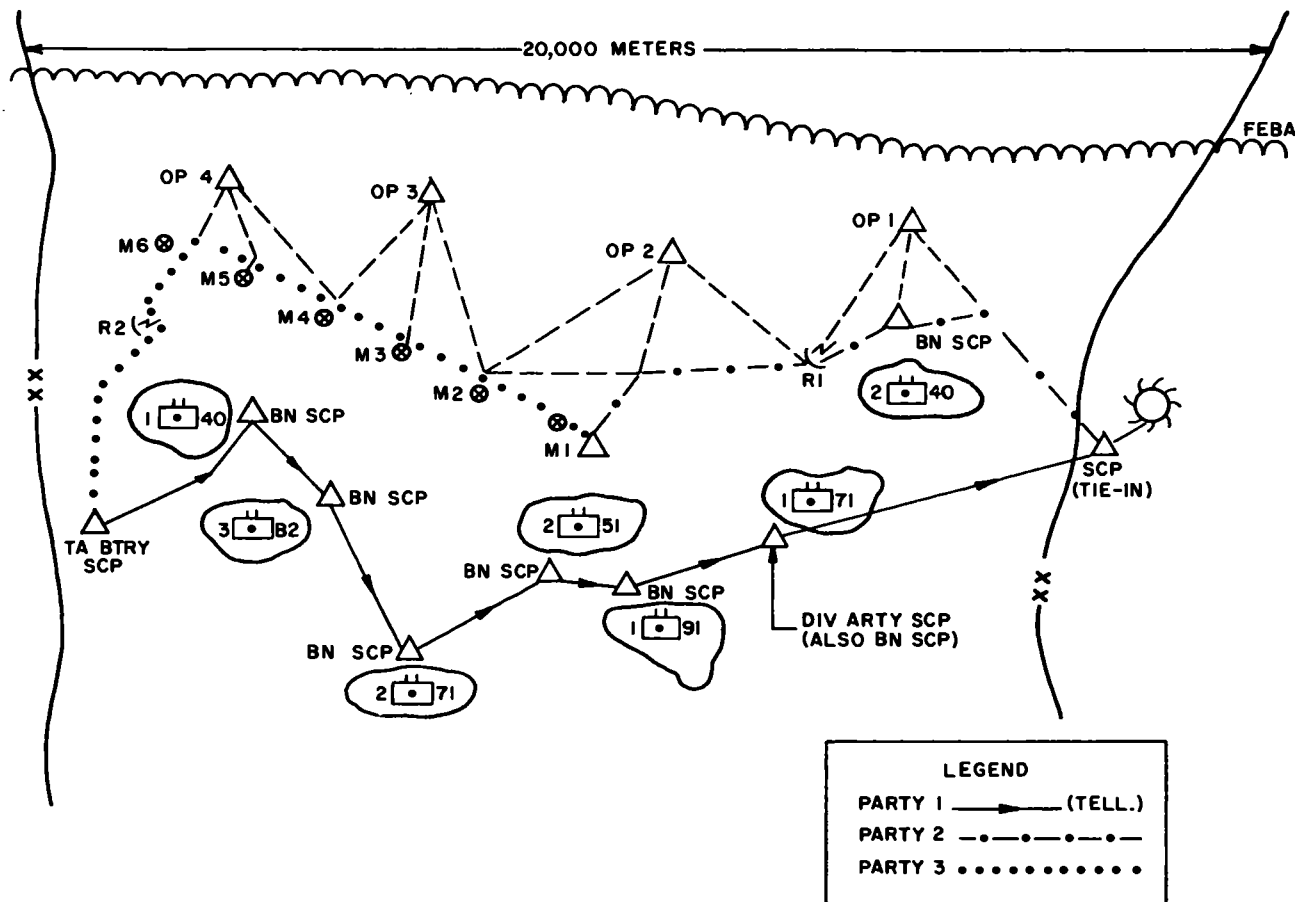


Figure 125. Target acquisition battery survey during the initial phase.

commander must incorporate them in his survey plan.

309. Target Acquisition Battery Survey Platoon Operations During the Initial Phase

a. The survey operations performed by a target acquisition battery survey platoon during the initial phase consist of the survey operations necessary to locate the target acquisition battery installations that require survey control and to provide a survey control point for the division artillery and for each corps artillery battalion in the platoon's area of responsibility.

b. All or part of the target acquisition battery survey operations are frequently started with assumed coordinates and height. For example, if survey control points do not exist in the vicinity of the selected sound base microphones, the sound base survey (and location of any survey control points along the line of the

sound base) is frequently performed by two parties starting at a point near the center of the sound base with assumed data. A third party extends survey control to the starting point.

c. An example of the survey operations conducted by a target acquisition battery survey platoon during the initial phase is shown in figure 125. The survey operations were accomplished by the two traverse parties and one tellurometer traverse party.

d. Party number 1 (tellurometer party) has been assigned the task of extending control from the target acquisition battery survey control point to several corps field artillery battalion survey control points, the division artillery survey control points, and a survey control point tie-in with the adjacent zone. Since this party is equipped with the tellurometer, its area of operations is more extensive than that of either of the two standard traverse parties.

An astronomic observation is used to check direction at the tie-in survey control point.

e. Party number 2 initiates its survey at the tie-in survey control point and locates two flash ranging observation posts (OP 1 and OP 2), a counterbattery radar (R1), and a battalion survey control point and closes on a previously agreed upon survey control point near the center of the sector.

f. Party number 3 initiates its survey at a previously established battalion survey control point and locates radar 2, OP 3, OP 4, and the six microphones of the sound base. This party closes its survey on the same survey control point used by party number 2 as a closing point.

310. Target Acquisition Battery Survey Platoon Operations Required to Complete the Initial Phase

The initial phase survey operations performed by the survey platoon of a target acquisition battery include the operations necessary to close all traverses and to check all intersected and resected points. It also includes the operations necessary to establish a declination station in the division area and to determine the locations of survey control points that are also located by the target acquisition battery survey platoons operating in the adjacent division areas. The initial phase survey operations of the battalion are considered to end when these operations have been performed by the survey platoons of each of the target acquisition batteries.

311. Survey Operations During the Expansion Phase

a. Survey operations of the target acquisition battalion during the expansion phase consist of establishing a basic net throughout the corps area, usually by triangulation or tellurometer traverse. From stations of the basic net, control then is extended, usually by traverse, so as to provide survey control throughout the corps area. The ultimate goal is a survey control point within 1,500 to 2,000 meters of every possible artillery position. This goal is accomplished to the extent permitted by the time available.

b. During the expansion phase, the survey platoons of the battalion are assigned tasks by the battalion survey officer as necessary to ac-

complish the required survey operations. The survey platoon of each battery should be assigned tasks in areas as near as possible to its battery area to facilitate future operations of the corps and to reduce the problems of movement from the battery area and messing.

c. Figure 126 is an example of the survey operation conducted by a target acquisition battalion during the initial phase (the critical traverse stations shown in black are those at which a traverse is initiated or closed). Figure 127 shows an example of the survey operations of a target acquisition battalion during the expansion phase.

312. Extension of Survey Control from Rear Areas

When the only existing survey control is a considerable distance to the rear of the corps area, control should, if possible, be extended to the corps area by engineer topographic units. When this is not possible, the target acquisition battalion may be required to extend control to the corps area; this normally is accomplished by the use of tellurometer traverse schemes. This extension of control may be initiated during either the initial phase or during the expansion phase, depending on the situation. When it is initiated during the initial phase, it is usually accomplished by the headquarters battery survey platoon. (The battery survey platoons may be required to furnish one or more tellurometer traverse parties to assist in these operations.)

313. Survey Control for Counterbattery Radar

Target acquisition battalion personnel must be familiar with the procedures used to establish survey control for counterbattery radar. These procedures are the same as those used to establish survey control for countermortar radar.

314. Survey Control for Sound Ranging Microphones

a. The survey operations necessary to establish survey control for a sound ranging microphone depend on the type of sound base selected by the sound ranging personnel. When the microphones are employed in an irregular base, the microphone positions are marked (either with a stake or with a microphone) by sound

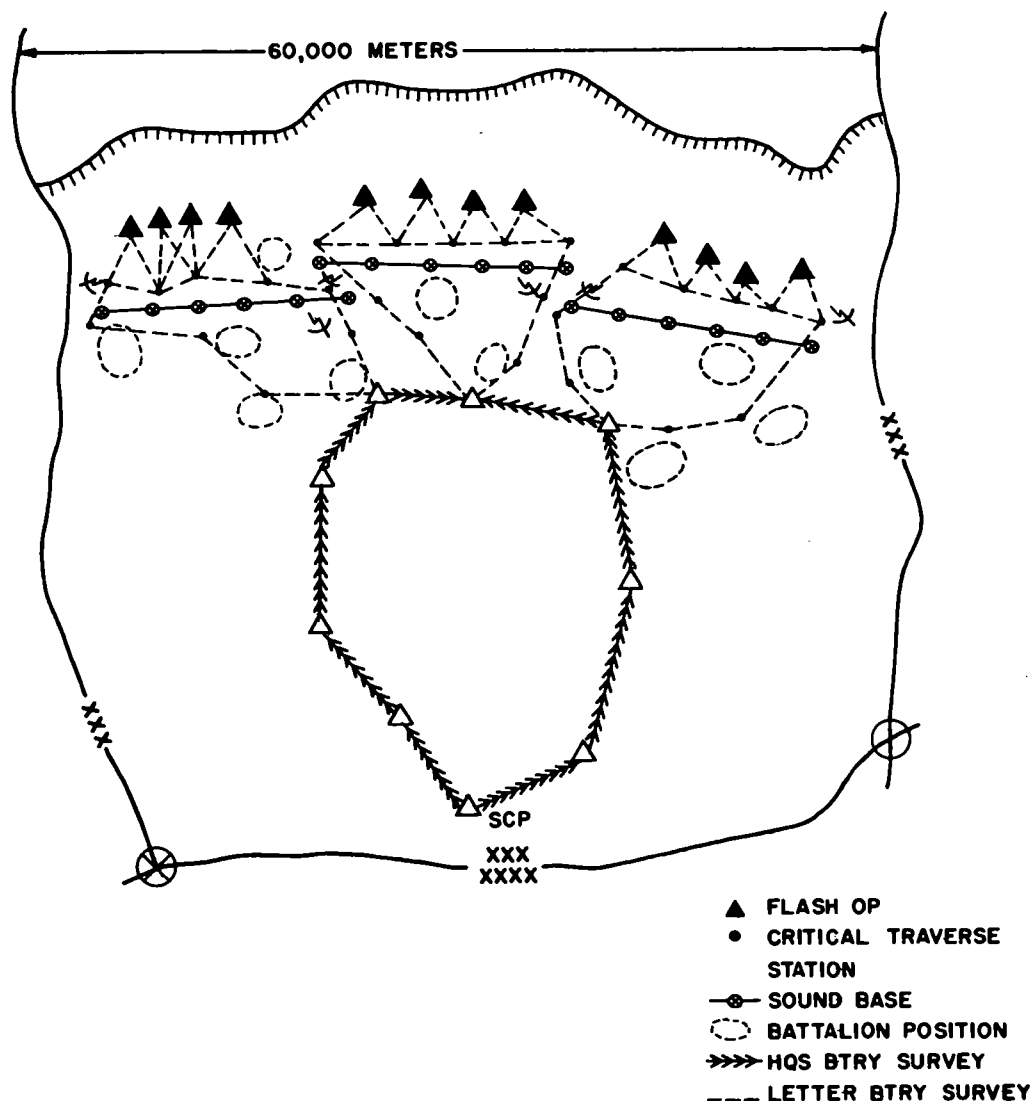


Figure 126. Target acquisition battalion survey operations during the initial phase.

ranging personnel. The location of each irregular-base microphone is determined in the manner used to locate any other survey station. When the microphones are employed in a regular base, the coordinates of each microphone are predetermined by computation. The points on the ground that correspond to the predetermined coordinates are then established; this is accomplished as indicated in (1) through (5) below—

- (1) A traverse is performed roughly parallel to the line of the sound base, following the best traverse route. A traverse station is established within 200 meters of each microphone position,

at a point from which the microphone position should be visible.

- (2) The azimuth and distance from the traverse station to the microphone position are computed by using the coordinates of the traverse station and the predetermined coordinates of the microphone computed on DA Form 6-1.
- (3) The direction of the microphone position is established by setting off on the theodolite the horizontal angle at the traverse station from the rear traverse station to the microphone position. This angle is determined by

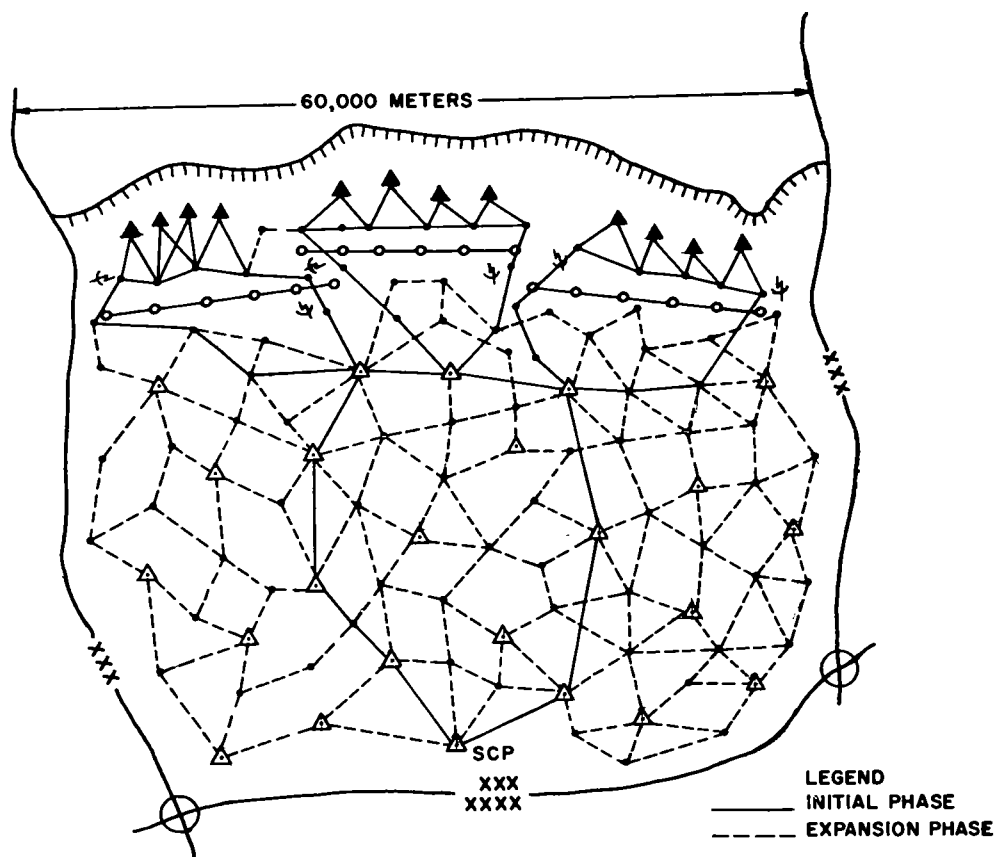


Figure 127. Target acquisition battalion survey operations during the expansion phase.

subtracting the azimuth to the rear traverse station from the azimuth to the microphone position. (The value that must be set on the horizontal circle of the theodolite is equal to the sum of the initial circle setting (the horizontal circle reading when the instrument is pointed at the rear traverse station) and the (computed) horizontal angle. As an example, assume that the initial circle setting is $0^{\circ}00'37''$ and that the computed horizontal angle is $173^{\circ}43'27''$. The value that must be set on the horizontal circle of the theodolite, set $04'04''$ on the micrometer scale, using the coincidence knob; set $173^{\circ}40'$ on the horizontal circle, using the horizontal motions.)

- (4) A ranging pole is placed on the line of sight through the telescope at a

distance approximately equal to the distance to the microphone. (The rodman should pace this distance to insure that large errors in taping do not occur.)

- (5) A taping team then tapes the computed distance from the traverse station to the microphone position and places a hub at the microphone position. (To prevent errors, the front tapeman should give all taping pins to the rear tapeman except those actually required to make the distance measurement. If it is necessary to break tape, the normal pin procedure should be followed. When the front tapeman has placed his last pin in the ground, he should pull the tape forward a partial tape length so that the rear tapeman can hold the proper graduation over the last taping pin. The front tapeman should place the hub in the ground, at the point directly

under the zero graduation on the tape. The tapeman should then check the distance by measuring the distance from the hub to the traverse station, using normal taping procedures. As an example of the method of establishing the distance, assume that the distance from the traverse station to the microphone position is 130.67 meters. This distance consists of four full tape lengths and a partial tape length of 10.67 meters. The front tapeman gives seven taping pins to the rear tapeman (retaining four pins) before starting the distance measurement. When the front tapeman has placed his fourth pin in the ground, he pulls the tape forward a partial tape length so that the rear tapeman can hold the 10.67-meter graduation directly over the last taping pin. The front tapeman places the hub in the ground under the zero graduation on the tape.)

b. The location of the microphone position hub can be checked by using the hub as a traverse station. It can also be checked by measuring the direction to the hub from a traverse station other than the one used to establish the microphone position and by comparing the measured direction with the computed direction to the hub.

c. If sound ranging microphones are established from a traverse based on assumed data for the starting station, the coordinates of the microphone positions must be converted to the common grid when the correct grid data for the starting point become available. *No change in the ground location of the microphone is required.*

315. Survey Control for Flash Ranging Observation Posts (Long Base)

Flash ranging observation posts are located in the same manner as observation posts for field artillery battalions except they must be located to an accuracy of fourth-order.

CHAPTER 19

OTHER ARTILLERY UNIT SURVEYS

Section I. FIELD ARTILLERY GROUP SURVEYS

316. Field Artillery Group

a. The field artillery group headquarters battery does not perform survey operations. The battalions of the group are normally furnished survey control by the artillery headquarters with which the group is working. When survey has not been furnished by the artillery headquarters with which the group is working, the group commander may designate one battalion to establish a group survey control point. When heavy or very heavy battalions of a group are required to perform target area surveys, the group commander usually designates one of the battalions of the group to perform the target area surveys for all of the battalions of the group.

b. The group assistant intelligence officer (assistant S2) is also the group survey officer. During training, the group survey officer supervises the training of the survey personnel of the battalions of the group. The group survey

officer coordinates the survey operations of the battalions of the group. He verifies that survey control points are provided by the next higher survey echelon. He verifies, by frequent inspections, that the survey sections of the group battalions perform survey operations properly. Two enlisted survey specialists are assigned to group headquarters battery for the purpose of assisting the group survey officer in carrying out his responsibilities. The group headquarters battery is not issued survey equipment.

317. Field Artillery Battalion Group

In addition to the normal survey responsibilities, the commander of a battalion group has survey responsibilities similar to those of a group commander. If survey control has not been furnished to the battalion group by the artillery headquarters with which it is working, the commander of the battalion group directs the survey officer of his battalion to establish a group survey control point.

Section II. FIELD ARTILLERY MISSILE COMMAND SURVEYS

318. Field Artillery Missile Command, Medium

a. The survey requirement of the missile command, medium consists of the location and orientation of the weapons and target locating installations of the command, guidance equipment in the Corporal missile battalion, tracking and plotting equipment in the drone platoons, meteorological equipment and ground based navigational aids for Army aviators.

b. The missile command has organic topographic engineer surveyors and field artillery target acquisition surveyors to provide the re-

quired survey control. The survey element of the engineer combat company (or engineer service and support company) has the responsibility for establishing eight third-order survey control points, equally spaced across the width of the missile command. The target acquisition battalion survey personnel extend the control from these survey control points to each of the battalions of the missile command. The missile battalions are organized under two group headquarters. Since the artillery group has no survey personnel and equipment, the target acquisition battalion survey parties provide the

control to the battalions directly. The target acquisition battalion survey parties provide this control to a prescribed accuracy of fourth-order.

c. The missile battalions of the command have organic survey parties to perform the internal survey. The parties are required to determine the location of the launchers to fifth-order accuracy. The survey parties must also provide orientation data for the launchers and guidance elements.

d. The target acquisition battalion commander is the missile command survey officer. He is a special staff member, and he advises the missile command commander on matters pertaining to survey in the command. He coordinates the survey efforts of the topographic engineer surveyors and the survey parties of the target acquisition battalion.

319. Field Artillery Missile Command, Air Transportable

a. The survey requirement of the missile

command, air transportable, consists of the location and orientation of the weapons and target locating installations of the command. The firing element of the missile command is one HONEST JOHN (LITTLE JOHN) battalion. The survey officer for the missile command, air transportable, is the survey officer of the HONEST JOHN (LITTLE JOHN) battalion. There are no target acquisition battalion or battery survey personnel authorized in the missile command, air transportable.

b. The missile command, air transportable, receives engineer survey support from the topographic engineer survey section of the organic engineer combat company. The engineer survey personnel establish survey control points as required by the HONEST JOHN battalion.

c. The HONEST JOHN (LITTLE JOHN) battalion has two eight-man survey parties which are used to extend control to each of the four launchers. They must locate the launchers to fifth-order accuracy and provide direction for orientation of the launchers and windsets.

Section III. AIR DEFENSE ARTILLERY SURVEYS

320. General

a. There are three major factors which determine the type of survey operations which must be performed by air defense artillery (ADA) units and the extent of those survey operations. These factors are—

- (1) The type of mission of a unit.
- (2) The availability of maps.
- (3) Restrictions placed on air defense fire.

b. When air defense artillery units are assigned air defense missions, they must be capable of transmitting, from one unit to another, information concerning the location of aircraft. To do this, they must be located with respect to a common grid. When suitable maps are available, units can be located with respect to a common grid by map inspection for both position and direction. When suitable maps are not available, units must be located with respect to a common grid by extending control to each unit from control points located on the grid.

c. When air defense artillery units are as-

signed air defense missions and are restricted from firing in certain areas, they must be located with respect to the grid on which the limits of the restricted areas are designated. They must be located on the grid by extending control to each fire unit from control points located on the grid.

d. When air defense artillery gun and missile units are assigned field artillery type missions, their survey requirements are the same as similar field artillery units.

321. Surveys for Air Defense Artillery Gun Battalions (Batteries)

a. When suitable maps are available and there are no restricted firing areas, survey control for a gun battalion is established by determining the location of a selected point (battalion SCP) by map inspection and by determining the azimuth from the battalion SCP to an azimuth mark by scaling from a map or by using a declinated aiming circle.

b. When suitable maps are available and there are restricted firing areas, survey control

is established by extending control to the battalion SCP from a control point located on the UTM (or UPS) grid for the zone. Direction is determined by astronomic observation or by measurement from a line of known direction. Survey operations are executed to a prescribed accuracy of fifth-order (1:1,000).

c. When suitable maps are not available, survey control for a gun battalion is established by extending control to a battalion SCP as discussed in *b* above.

d. Regardless of the method by which control is established for the battalion SCP, control is extended from the battalion SCP to each battery, to the battalion surveillance radar, and to a battalion radar range-calibration point by survey operations executed to a prescribed accuracy of fifth-order. The control which is established for these installations is as follows:

- (1) The horizontal and vertical locations of the antenna of the track radar for each battery.
- (2) The horizontal and vertical locations of the antenna of the battalion surveillance radar.
- (3) The horizontal and vertical locations of the battalion radar range-calibration point(s). (The slant range from the track radar of each battery to the radar range-calibration point for the battery must be computed.)
- (4) A line of known direction (orienting line) to a distant point from the track radar antenna of each battery and for the battalion surveillance radar.
- (5) When directed, the range and the vertical angle to the distant point ((4) above) from the track radar antenna of each battery. If the range and the vertical angle are not determined to the distant point, it is referred to as the *orienting point*. If the range and the vertical angle are determined to the distant point, it is referred to as the *known datum point* (KDP).

e. When directed, gun battalion survey personnel assist battery personnel in obtaining orientation data. Orientation data are determined by survey executed to a prescribed ac-

curacy of fifth-order. Orientation data that are obtained by survey consist of the following:

- (1) The easting, northing, and height components of the parallax from the center of the mass of metal (battery center or directing point) to the track radar antenna.
- (2) The lateral distance from each gun to the orienting line (*d*(4) above).
- (3) The easting, northing, and height components of the parallax from each gun to the track radar antenna.

322. Surveys for ADA AW Battalions (Batteries) Equipped With Electronic Fire Control and 75-mm Light ADA Battalions (Batteries)

a. When suitable maps are available and there are no restricted areas, survey control for each weapon is established by map inspection for position and by scaling from a map or by using a declinated aiming circle for direction.

b. When suitable maps are available and there are restricted areas, survey control is established by extending control to the battalion (detached battery) SCP from a control point located on the UTM (or UPS) grid for the zone. Direction is obtained by astronomic observation or by measurement from a line of known direction. Survey operations to extend control to the battalion SCP are performed to a prescribed accuracy of fifth-order.

c. When suitable maps are not available, survey control is established by extending control to the battalion (detached battery) SCP as stated in *b* above.

d. When there are restricted areas and/or when suitable maps are not available, the horizontal and vertical locations of each weapon are determined, and a line of known direction for each weapon is established by extending control to each weapon from the battalion (detached battery) SCP. Survey operations to extend the control are performed to a prescribed accuracy of fifth-order.

e. Regardless of the method used to determine the location of a weapon, the slant range from each weapon to the radar range-calibration point is determined for each weapon by survey operations executed to a prescribed accuracy of fifth-order.

323. Surveys for ADA AW Battalions not Equipped With Electronic Fire Control

a. Survey control is not required for ADA AW battalions not equipped with electronic fire control when there are no restricted areas. However, the relative locations of weapons and early warning observation posts must be known so that an early warning system can be established. When suitable maps are available, the relative locations of the weapons and observation posts are determined by map inspection. When suitable maps are not available, the relative locations can be established by limited rough survey as explained in FM 21-26.

b. When there are restricted areas, survey control is established to determine the relative horizontal and vertical locations of each weapon and to provide an orienting line for each weapon. Survey control is extended from survey control points established within 1,000 meters of the position area of each weapon by survey operations performed to a prescribed accuracy of 1:500.

c. When ADA AW battalions are required to accomplish the surveys discussed in *b* above, necessary surveying equipment (two aiming circles per battery and one per battalion headquarters) must be made available from sources outside the battalion.

324. Surveillance Radars

a. Each ADA surveillance radar must be established on the UTM (or UPS) grid for the zone. When suitable maps are available, this is accomplished by map inspection for position by scaling from a map or by using a declinated aiming circle for direction.

b. When suitable maps are not available, the horizontal and vertical locations of each surveillance radar are determined, and a line of known direction is established by extending control from a control point on the UTM (or UPS) grid for the zone by survey operations executed to a prescribed accuracy of fifth-order.

c. Air defense artillery battalions normally are not capable of performing survey. The control must be extended by an agency having suitable survey equipment and trained survey personnel. Arrangements should be made for the nearest engineer or artillery unit capable of providing the control to perform the necessary survey operations.

325. Air Defense Artillery Missile Battalions

The target-tracking radar of ADA missile battalions must be established on the UTM (or UPS) grid for the zone. A line of known direction from that radar on the grid for the zone must be established. For permanently emplaced battalions, necessary survey operations are performed by engineer personnel. For semimobile battalions, the necessary control may be established by scaling from a map, when suitable maps are available, or by using a declinated aiming circle for direction. When suitable maps are not available, survey control is provided by engineer personnel or extended by the missile battalion personnel from a survey control point located within 1,000 meters of the target-tracking radar. The control is extended by survey operations executed to a prescribed accuracy of fifth-order.

326. ADA Missile Battalions in FA Role

The missile-tracking radar of ADA missile battalions employed in the field artillery role must be established on the UTM (or UPS) grid for the zone. A line of known direction from that radar on the grid for the zone must be established. When ADA missile battalions are employed in the field artillery role, necessary survey personnel are provided in the TOE. A survey control point must be provided by engineer personnel or target acquisition battalion survey personnel within 2,000 meters of the missile-tracking radar. The missile battalion survey personnel extend the control to the radar and launcher positions to a prescribed accuracy of fifth-order.

CHAPTER 20

SURVEY PLANNING

Section I. GENERAL

327. Survey Mission

a. The general mission of artillery survey personnel is to provide accurate and timely survey information and control to artillery units and installations. Successful accomplishment of this mission requires careful survey planning and the formulation of a survey plan which is as complete as possible.

b. The specific mission of artillery survey personnel for any survey operation is contained in orders and instructions issued by the organization commander. These orders and instructions are contained in the unit SOP, operations orders and training directives.

c. After the commander has issued orders and/or instructions which require the execution of survey operations, the survey officer must plan the survey operations and issue necessary instructions to survey personnel to execute the assigned mission.

d. In some situations the survey officer may be required to prepare plans for proposed survey operations. The survey officer may be required to submit the proposed plans to the commander or his representative for consideration. (During combat, the survey officer usually is not required to submit the survey plan to the commander or his representative when survey operations are to be initiated immediately.)

328. Information Furnished the Survey Officer by the Commander

In addition to the specific survey instructions, the commander or his representative should furnish the survey officer certain information which he must have to plan the survey

operations. The information which the survey officer should receive *includes* the following:

a. *Situation.* During combat, the survey officer should know both the enemy and friendly situations as they affect the unit mission and especially as they affect survey operations.

b. *Mission of the Unit.* The survey officer should know the mission of the unit and plan the survey operations so that they will best assist in the accomplishment of the unit mission.

c. *Time Available for Survey Operations.* The time available for survey operations may be specified by the commander or it may be indicated by the unit mission. The time available dictates the amount of survey that can be accomplished and whether limited time or deliberate survey methods are to be used. If the time available for survey operations is not specified, they should be accomplished as soon as possible consistent with other requirements.

d. *Installations That Require Survey Control and Their Locations.* The installations that require survey control usually will be specified in the SOP. For each situation, the commander will indicate only those installations requiring survey control that are not included in the SOP. The general location of units that require survey control usually will be indicated in the commander's orders or instructions and may be furnished on a map overlay. The survey officer usually will have to determine the exact location of installations by reconnaissance.

e. *Location of the Installation to Which Survey Data Must Be Furnished.* The survey offi-

cer must know the location of the installation (e.g., FDC for field artillery battalions) to which survey data must be submitted. The location of this installation must be known so that the submission of data will not be delayed. The location of this installation usually will be indicated by the commander.

f. Survey Requirements for Each Installation. The survey requirements for each installation usually will be specified in the SOP by the commander.

g. Survey Control Available. Information concerning available survey control may be furnished to the survey officer by the commander or his representative. However, the survey officer usually will obtain the information from trig lists issued by higher headquarters and by personal contact with survey personnel of higher headquarters.

h. Personnel Available for Survey Operations. The commander usually will specify in the SOP the personnel that are available for survey operations. He then usually will specify for a given operation any differences from the SOP in the personnel available.

i. Restrictions on Survey Operations. Certain restrictions on survey operations may be specified by the commander. Most restrictions on survey operations will be dictated by such things as the situation, the mission, the availability of personnel, etc.

329. Factors Affecting Survey Planning

The artillery survey officer must consider many factors in formulating the plan by which the survey mission is to be accomplished. The factors which affect survey planning cannot be considered independently because each factor is related to other factors. The most important of these factors are discussed in paragraphs 330 through 338.

330. Situation as it Affects Survey Operations

The survey planner must consider both the enemy and the friendly situations as they affect survey operations. He must consider capabilities of the enemy to interfere with or restrict survey operations. He must consider the locations of friendly elements and their missions. He must consider any restrictions

that the situation places on travel and/or communication.

331. Number and Locations of Installations Requiring Survey Control

The number and locations of installations that require survey control must be considered primarily with respect to time and personnel available. The survey operations necessary to locate a small number of widely scattered installations will often require more time and/or personnel than would be required for a large number of closely grouped installations. In the survey plan, the survey tasks should be so allocated that the various parties executing the survey will complete their tasks at approximately the same time. This might require, for example, the use of two parties to establish control for one installation which is at a considerable distance from the starting point while one party is establishing control for three installations which are relatively close to the starting point.

332. Survey Requirements for Each Installation Requiring Survey Control

The survey planner must know the requirements of each installation for which control must be provided. For example, the light, medium, and the heavy field artillery battalion survey parties must locate each battery center whereas the very heavy field artillery battalion survey parties must locate each piece.

333. Survey Control Available

More extensive survey operations are required in areas where limited survey control exists than are required in areas where survey control is dense.

334. Survey Missions

The field artillery battalion survey operations must provide the best possible survey data in the time available. The division artillery survey operations must provide timely and accurate survey control to subordinate units. Corps artillery must provide timely and accurate survey control to the artillery with the corps.

335. Number and Status of Training of Survey Personnel

The survey plan must be based on the use of survey methods that are completely familiar to all personnel. Sufficient trained personnel

must be made available to perform the required survey operations in the allotted time.

336. Type of Terrain Over Which the Survey Must Be Performed

a. The visibility, the type of terrain, and the number and locations of installations requiring survey control are the primary factors which should be considered in determining the survey methods to be used and the amount of time and number of personnel required to accomplish the survey mission.

b. The survey officer should be so familiar with the effects that various types of terrain have on survey operations that he can promptly and properly advise his commander on the time and personnel requirements for survey operations.

337. Weather Conditions

Bad weather may eliminate or greatly reduce the capability of survey. For example,

poor visibility may require the use of the magnetic needle for determination of a starting direction. Icy slopes reduce taping accuracy. Poor visibility requires shorter distances between stations necessitating more angle turning stations. Trilateration can often be conducted during periods when poor visibility precludes the execution of other survey operations.

338. Availability of Special Survey Equipment

Consideration must be given to the availability and operational readiness of such special survey equipment as the tellurometer and artillery gyro azimuth instrument. The presence or lack of such equipment can greatly affect the time and work required for a survey operation. In addition, proper use of special techniques, such as simultaneous observation, can materially affect the accomplishment of the survey mission.

Section II. STEPS IN SURVEY PLANNING

339. General

The steps in survey planning are obtaining information (warning order), map reconnaissance, ground reconnaissance, and formulation of the survey plan. They are discussed in paragraphs 340 through 343.

340. Obtaining Information

Obtaining information on mission, terrain, and situation is a continuing process in survey planning that commences when the commander briefs his staff and subordinate commanders.

341. Map Reconnaissance

A map reconnaissance is performed by using any suitable map or map substitute. The first step in making a map reconnaissance is to plot the installations requiring control on the map. The survey officer then considers the factors affecting survey planning and—

a. Makes a tentative choice of survey methods. (In selecting survey methods, the survey officer should choose between traverse and triangulation when possible.)

b. Determines whether the survey mission can be accomplished in the allotted time with

the personnel available. (If it cannot, he makes appropriate recommendations to his commander. For example, he can recommend that additional survey personnel be made available, that the time allotted for survey be increased, and/or that certain installations be given a low priority.)

c. Makes a tentative survey plan, noting the critical areas which will require detailed ground reconnaissance.

d. Issues necessary warning order to survey personnel.

342. Ground Reconnaissance

The survey officer makes as complete a reconnaissance of the ground as time permits. He makes a general reconnaissance of the entire area and a detailed reconnaissance of those critical areas noted during the map and the general ground reconnaissance. The general ground reconnaissance can be performed by motor vehicle, aircraft, or other means, but the detailed ground reconnaissance should be performed on foot. If no suitable map or map substitute is available, the survey officer must take the action indicated in paragraph 341

after performing the general ground reconnaissance but before performing the detailed ground reconnaissance.

343. Formulation of the Survey Plan

On completion of the ground reconnaissance, the survey officer formulates the survey plan.

Section III. THE SURVEY PLAN

344. General

The survey plan contains those detailed instructions for each survey party not covered by standing operating procedure and general information necessary for the efficient accomplishment of the survey mission.

345. Sequence in Which Survey Plan Is Issued

The survey plan is issued orally. It should be issued in the sequence listed below, which is the five-paragraph sequence in which an operation order is issued.

1. SITUATION (as it affects the survey operations)
 - a. Enemy.
 - b. Friendly.
 - c. Attachments and detachments.
2. MISSION (survey)
3. EXECUTION
 - a. Concept of survey operations.
 - b. Detailed instructions to each party.
 - c. Instructions for more than one party.
4. ADMINISTRATION AND LOGISTICS (supply)
5. COMMAND AND SIGNAL (location of survey officer)

346. Changes to the Survey Plan

During the execution of the survey, the sur-

vey officer closely supervises the work of the survey parties to insure that the survey plan is properly executed and to detect any changes in the survey plan which may be necessary. If it becomes necessary to change the plan, he issues appropriate instructions to the party chief(s) concerned.

347. Execution of the Survey Plan

Each chief of survey party plans the detailed operations of his party. His planning is similar to that of the survey officer. The mission of his survey party is contained in the instructions issued by the survey officer. The survey plan prepared and issued by the chief of party contains those items from the survey officer's plan which his personnel should know to accomplish the survey mission and any additional instructions which are necessary. The chief of party supervises the operations of his party and issues additional instructions as necessary throughout the conduct of the survey. Whenever it becomes impracticable to comply with the instructions received from the survey officer, he reports this fact to the survey officer or chief surveyor if either is immediately available. If neither is immediately available, the chief of party changes his survey plan as necessary to accomplish that portion of the unit's survey mission for which he is responsible. At the first opportunity, he reports to the survey officer the action which he has taken.

Section IV. STANDING OPERATING PROCEDURE

348. General

a. A standing operating procedure is a set of instructions which gives the procedures that are to be followed for those phases of operation which the commander desires to make routine (FM 101-5). The SOP sets down the regular procedures that are to be followed in the absence of instructions to the contrary.

b. The SOP of a battalion (separate battery)

or higher artillery headquarters should contain a section on survey. The SOP for each echelon must conform to the SOP of the next higher echelon. Therefore, the survey portion of the SOP at each artillery echelon should contain only those survey procedures which the commander desires to make standard throughout the command. Survey items which the commander desires to make standard only for the survey unit or section of his headquarters

should be contained in the SOP for that unit or section.

349. Purposes of Survey Section SOP

The purposes of the survey section SOP are—

a. To Simplify the Transmission of the Survey Plan. Instructions included in a SOP need not be restated in the survey plan. For example, if the battalion SOP prescribed the size of distance angles for triangulation, this information need not be included in the survey plan. However, inclusion of this information in the SOP would not prevent the survey officer from restating it in the survey plan for emphasis.

b. To Simplify and Perfect the Training of Survey Personnel. Establishment of standard

procedures for survey operations in a unit insures uniform training and minimizes the need for special instruction.

c. To Promote Understanding and Teamwork. In those units which have more than one survey party, establishment of standard procedures insures uniform performance of survey operations and minimizes the time and effort required for coordination.

d. To Facilitate and Expedite Survey Operations and To Minimize Confusion and Errors. When personnel become familiar with, and employ, standard signals, techniques, and procedures, they will accomplish their tasks in a minimum amount of time. Furthermore, use of standard procedures reduces confusion and eliminates many errors, which, in turn, expedites survey operations.

PART FIVE

DETERMINATION OF AZIMUTH BY ASTRONOMIC OBSERVATIONS

CHAPTER 21

BASIC ASTRONOMY

Section I. GENERAL

350. General

The effectiveness of any weapon delivery system depends on its position and orientation with respect to the target. The direction or azimuth required for orientation is determined by survey. The preceding chapters have shown how azimuth can be determined from existing survey control and extended by traverse or triangulation. This procedure, however, requires considerable time and may result in a possible loss of accuracy in extension. By observing celestial bodies, the surveyor is able to determine direction, when and where it is needed.

351. Application to Artillery Survey

Astronomic observations are made by the artillery surveyor to expedite the following survey operations:

- Determining a starting azimuth for a survey.
- Checking the closing azimuth of a survey.
- Providing orienting azimuths for cannons and rockets and associated fire control equipment.
- Providing orienting azimuths for missiles and associated guidance equipment.
- Determining azimuths for the declination of aiming circles.

352. The Earth

- Shape of the Earth.* The earth has the shape of an *oblate spheroid* (flattened sphere).

The line connecting the flattened ends of the earth is the *earth's rotating axis*, and the points at which the axis cuts the sphere are called the north and south poles, respectively.

- Motion of the Earth.* The earth rotates on its axis from west to east, making one complete rotation each day. As the earth rotates, it also revolves about the sun in an elliptical orbit (or plane), completing one revolution each year. If the earth's axis were perpendicular to this elliptical plane, the sun's rays would be directed at the Equator throughout the year and there would be no change in seasons. Because the axis is tilted $23^{\circ} 30'$ from the perpendicular to this elliptical plane, as the earth revolves about the sun, the rays of the sun are directed at different portions of the earth above or below the Equator (fig. 128).

- Geographic Coordinate System.* Since a rectangular coordinate system cannot be

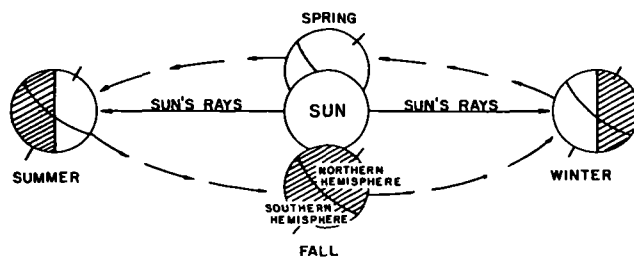


Figure 128. Earth's orbit showing change in seasons.

adapted to a sphere, a system utilizing angular measurements was adopted.

(1) *Longitude*. Planes were passed through the earth so that they intersected both poles. The lines which these planes inscribe on the surface of the sphere are called *meridians of longitude*. A base line for measurement was established when the meridian that passes through Greenwich, England, was given a value of 0° . Longitude is measured in degrees, minutes, and seconds both east and west of the Greenwich meridian. Longitude is identified as being east or west by the initials E (east) or W (west) (i.e., $90^\circ 24' 18''$ W or $40^\circ 12' 43''$ E).

(2) *Latitude*. Other planes were passed through the earth all parallel to each other and perpendicular to the earth's rotating axis. The lines inscribed on the earth's surface by these planes are called *parallels of latitude*. The parallel of latitude halfway between the poles is called the Equator, which is given a value of 0° and is used as a base for measurement of latitude. Latitude is measured in degrees, minutes, and seconds north and south of the Equator. Latitude is identified as being north or south by the initials N (north) or S (south) (i.e., $34^\circ 48' 12''$ N or $30^\circ 12' 16''$ S).

353. The Celestial Sphere

In practical astronomy, it is assumed that the sun and stars are attached to a giant sphere, the center of which is the earth. The stars are so far away from the earth that the radius of the sphere can be assumed to be infinite. It is also assumed that the earth stands still and that the sun and stars on this celestial sphere revolve around the earth. Some parts of the celestial sphere are related to parts of the earth (fig. 129).

a. The points at which the extensions of the earth's rotating axis intercept the celestial sphere are called the *north* and *south celestial poles*, respectively.

b. The plane forming the earth's equator

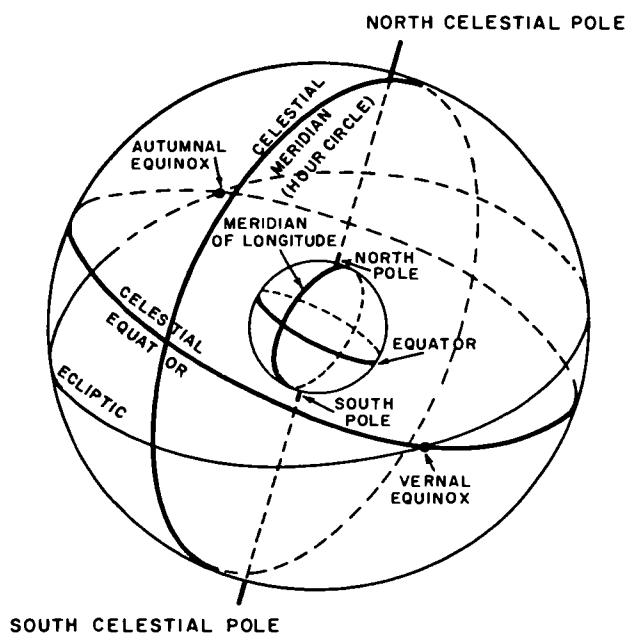


Figure 129. The celestial sphere.

when extended to the celestial sphere inscribes the *celestial equator* on the celestial sphere.

c. The extension of any plane forming a meridian of longitude when extended to the celestial sphere forms a corresponding line on the celestial sphere which is called a *celestial meridian* or *hour circle*.

d. The *ecliptic* is the great circle cut on the celestial sphere by the plane of the earth's orbit. Since the earth is assumed to be stationary, the ecliptic is assumed to be the path of the sun. The ecliptic intersects the celestial equator at two points at an angle of about $23\frac{1}{2}^\circ$.

e. The point at which the sun crosses the celestial equator moving from south to north is known as the *vernal equinox*. The point at which the sun crosses the celestial equator moving from north to south is known as the *autumnal equinox* (fig. 129). The equinoxes are imaginary fixed points on the celestial sphere and revolve about the earth with the stars. The sun occupies the same position as the vernal equinox once each year on or about the 21st of March and the same position as the autumnal equinox on or about the 21st of September.

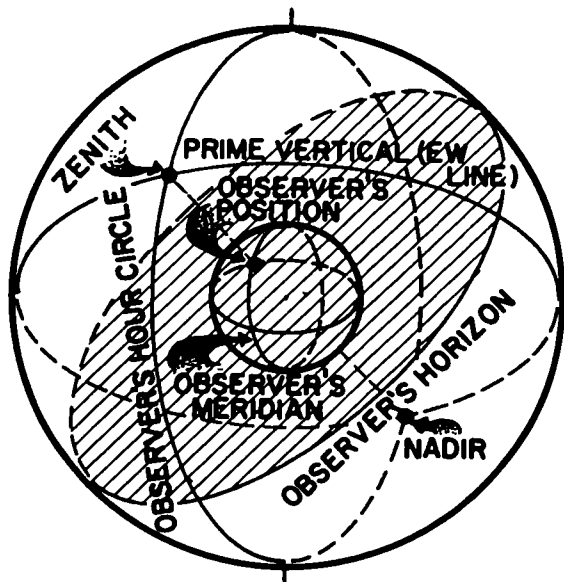


Figure 130. Elements relative to observer's position.

354. Observer's Position

a. The *zenith* and *nadir* for any point on the earth's surface are the two points on the celestial sphere where the extended plumb line of the observer's instrument intersects the sphere. The zenith is the point directly above and the nadir is the point directly below.

b. The observer's geographic locations are as follows:

- (1) The latitude of the observer's location is the angular distance of that point north or south of the Equator.
- (2) The longitude of the observer's location is the angular distance of the point east or west of the prime meridian.

c. The line of longitude which passes through the observer's position is called the *observer's meridian*, and the celestial meridian which passes through the zenith is called the *observer's hour circle* (fig. 130).

d. The *observer's horizon* is a great circle on the celestial sphere, formed by a plane tangent to the earth at the observer's location and the perpendicular to the plumb line of the observer's instrument (fig. 130).

e. A *vertical circle* is any circle on the celestial sphere passing through the zenith and nadir of a point (fig. 130).

f. The *prime vertical* is the vertical circle perpendicular to the observer's meridian at the zenith, which intersects the horizon at points directly east and west of the observer (fig. 130).

355. Position of a Celestial Body

The positions of celestial bodies are located in the sky by two methods:

a. *Equator System*. The celestial body is located on the celestial sphere much the same as the observer is located on the earth. The two coordinates in this system are *right ascension* (RA) and *declination* (dec) (fig. 131).

- (1) Right ascension is comparable to longitude and is the distance in hours (h), minutes (m), and seconds (s) measured eastward from the vernal equinox to the hour circle of a celestial body.
- (2) The declination of a celestial body is comparable to latitude and is the distance in degrees, minutes, and seconds measured north or south of the celestial equator to a celestial body. If the celestial body is north of the celestial

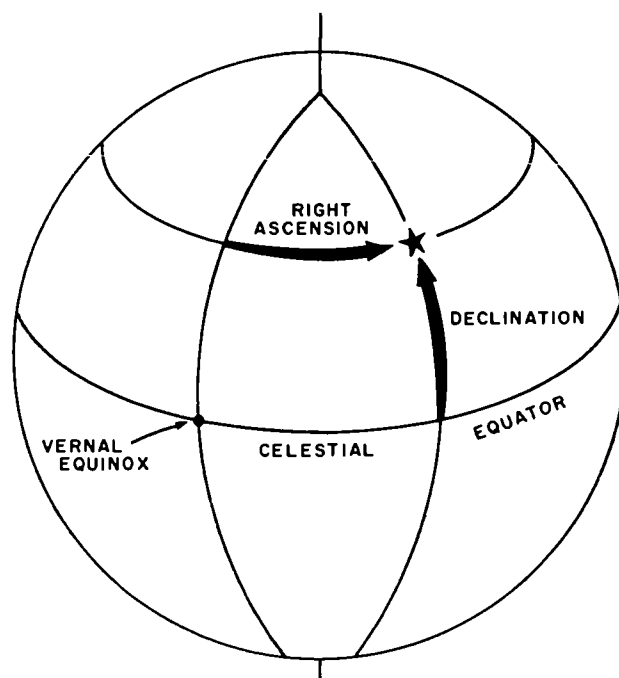


Figure 131. Equator system of locating a celestial body

equator, the declination is plus (+); if it is south, the declination is minus (—).

b. *Horizon System.* The celestial body may also be located in the sky with reference to the observer's known geographic location. The two coordinates of this system are *azimuth* and *altitude* (fig. 132). These coordinates can be used to locate the celestial body from one point for one time only, because the sun and stars change rapidly in location with reference to the position of an observer on the earth.

- (1) The azimuth to a celestial body from the observer can be either determined by computation of an astronomic observation of the celestial body or measured with an instrument from a known azimuth.
- (2) The altitude of a celestial body is the vertical angle measured at the observer's position from the observer's horizon to the celestial body.

356. Time

Two general classes of time are encountered in astronomy. These are *sidereal time* based

on the stars and *solar time* based on the sun. Both classes of time are based on one rotation of the earth about its axis, or 1 day. Assuming that the earth stands still, the day is based on one complete revolution of the celestial sphere (or the sun, for solar time), about the earth.

a. *Sidereal time (ST)* is based on a sidereal day or the length of time it takes a star to make a complete revolution around the earth. The point from which the sidereal day is measured is the vernal equinox. The sidereal day for any point begins when the vernal equinox crosses the meridian of that point and ends when the vernal equinox again crosses that meridian. Sidereal time for any point at any instant is the number of hours, minutes, and seconds that have elapsed since the vernal equinox last passed the meridian of that point. Sidereal time is not satisfactory for everyday use because the vernal equinox crosses a meridian at noon on the 21st of March, but each day thereafter it crosses about 3 minutes 56 seconds earlier so that on the 21st of September it crosses at midnight.

b. *Solar time* is based on a solar day. There are two types of solar days—one based on the apparent or actual movement of the sun and the other on a fictitious or mean sun.

- (1) Apparent solar time is based on the length of time that it takes the sun to make two successive crossings of the same meridian. Apparent solar days vary in length owing to the sun's inconsistent rate of movement along the ecliptic.
- (2) In order to have days of equal length, a mean solar day was devised which was based on a fictitious sun moving uniformly in its apparent path around the earth. This mean solar day is approximately the same length as the average apparent solar day. Mean solar time is based on this mean solar day which is divided into 24 hours, each consisting of 60 minutes.
- (3) The equation of time is the computed difference in hours, minutes, and seconds between apparent solar time and mean solar time. The equation of time varies from plus (+) 16 minutes to minus (—) 14 minutes. To convert

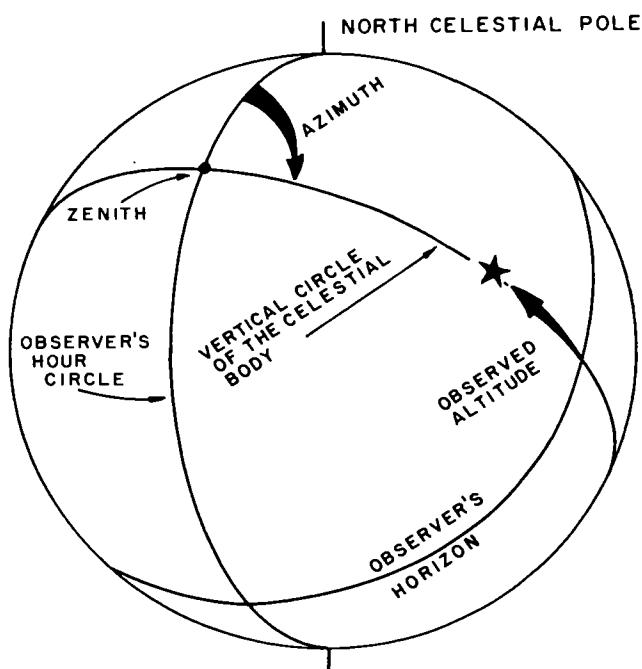


Figure 132. Horizon system of locating a celestial body

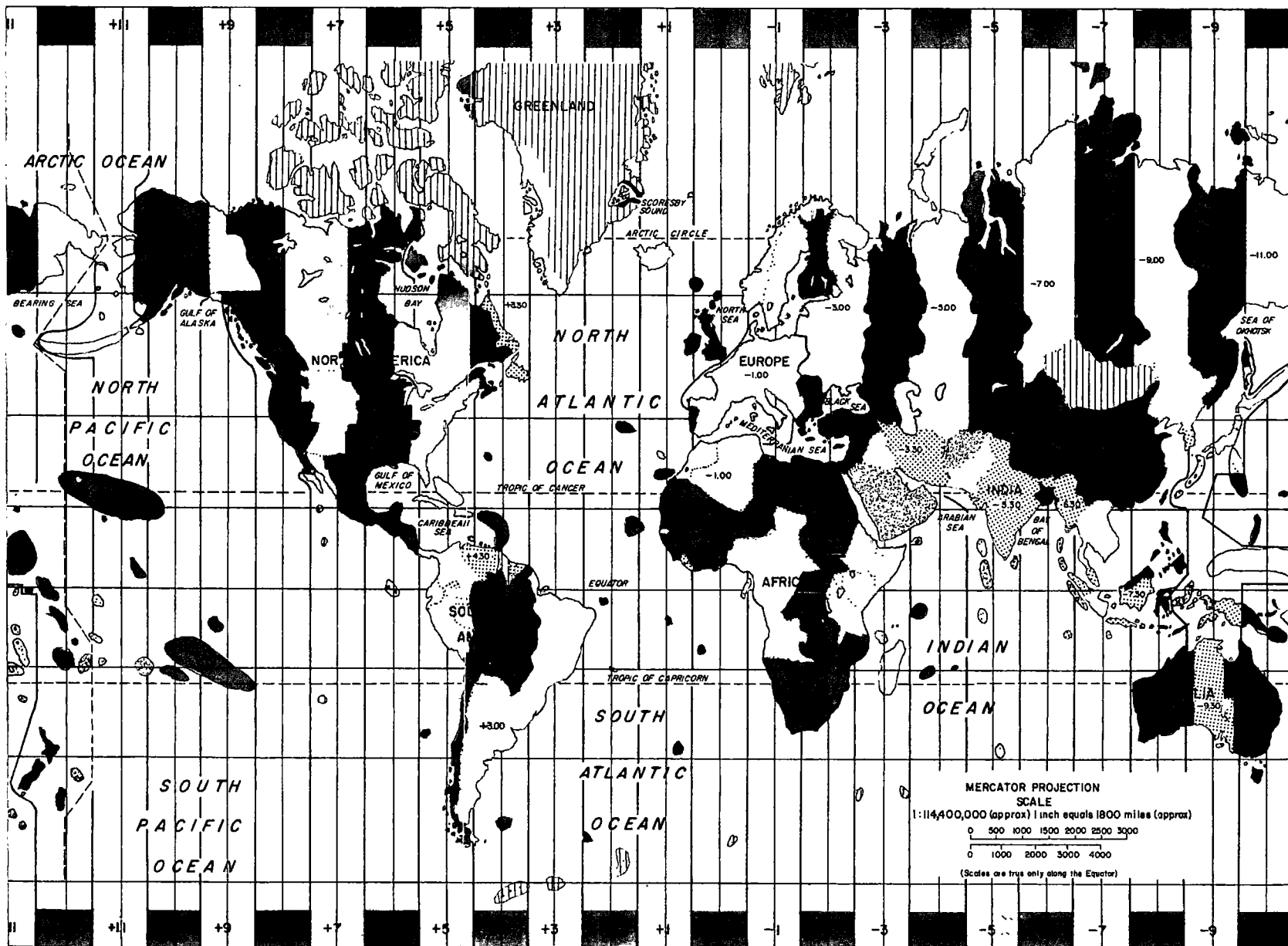


Figure 133. World time zones based on Greenwich mean time.

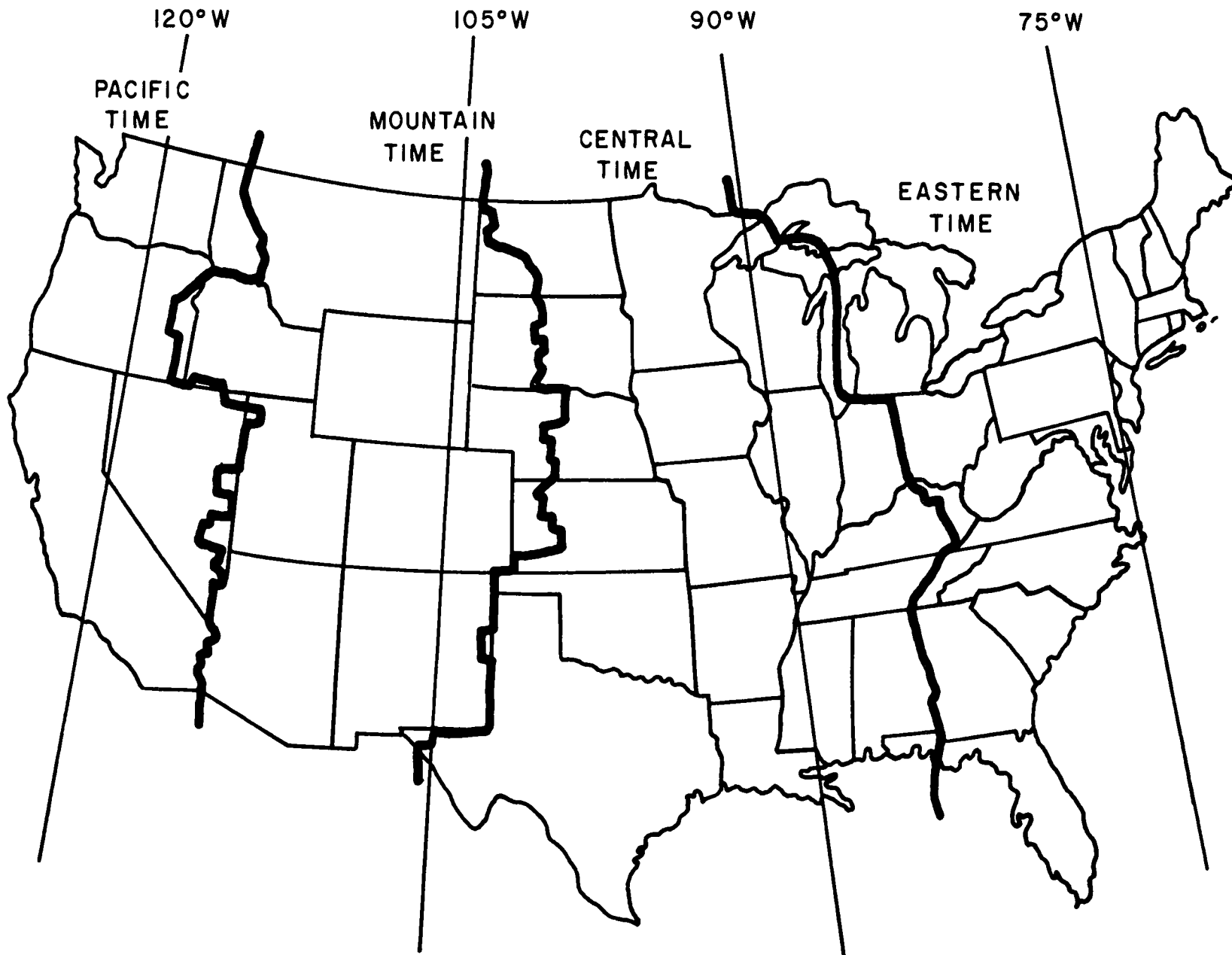


Figure 134. United States standard time zones.

mean solar time to apparent solar time, the equation of time is added algebraically to mean solar time.

357. Time Arc Relationship

Since the sun or stars apparently revolve around the earth once every 24 hours, then it follows that the apparent rate of movement on the celestial sphere is 15° of longitude or arc per hour.

358. Standard Time and Time Zones

Local mean time (*LMT*) changes 1 hour for each change of 15° of longitude. Since the sun moves from east to west, time increases from west to east and decreases from east to west. For example, with Greenwich as a baseline for time measurement, time changes 1 hour for each change of 15° of longitude (arc) westward from Greenwich. Time differs in whole hours from Greenwich mean time (*GMT*) at 15° W, 30° W, 45° W, etc. (fig. 133). To standardize the time within a certain area, lines of longitude at which time differs from Greenwich mean time in whole hours are used. A time zone area extending $7\frac{1}{2}^\circ$ from each side of these lines has the same time as that meridian unless otherwise specified by civil authorities. For example, the time zone for the 45° W meridian would extend from $37^\circ 30'$ W to $52^\circ 30'$ W. In the United States, there are four time zones (fig. 134). These zones are based on the 75° W, 90° W, 105° W, and 120° W meridians and are called eastern, central, mountain, and pacific standard times, respectively.

359. Greenwich Mean Time

All computations of astronomic observations in the artillery are based on Greenwich mean time. In order to determine Greenwich mean time for the local mean time of observation, a correction must be applied for the difference in hours between local mean time (standard time) and Greenwich mean time (standard of civil time) (fig. 135). For example, if the longitude of the observer is $92^\circ 13' 42''$ W and the civil or mean time at that point is based on the standard time of the 90° W meridian, then there is a 6-hour difference or correction to be applied to the local mean time of observation in order to determine the Greenwich mean time of observation.

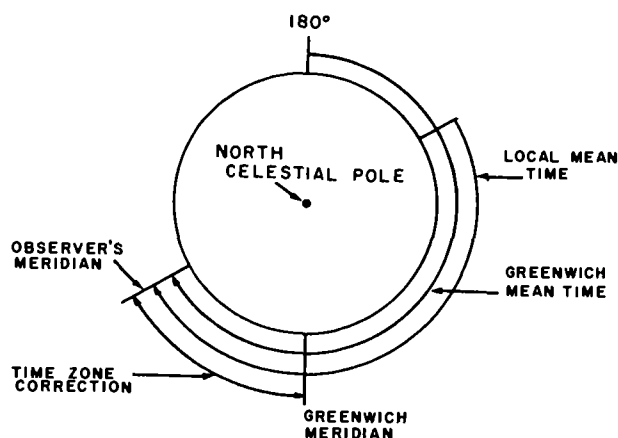


Figure 135. Greenwich mean time.

360. Greenwich Sidereal Time

Greenwich sidereal time (*GST*) is the length of time that has elapsed since the vernal equinox last crossed the Greenwich meridian (fig. 136). Greenwich sidereal time can be determined from Greenwich mean time by adding the sidereal time at 0^h Greenwich mean time on the date desired and the correction to sidereal time for Greenwich mean time to the Greenwich mean time. For example, if the

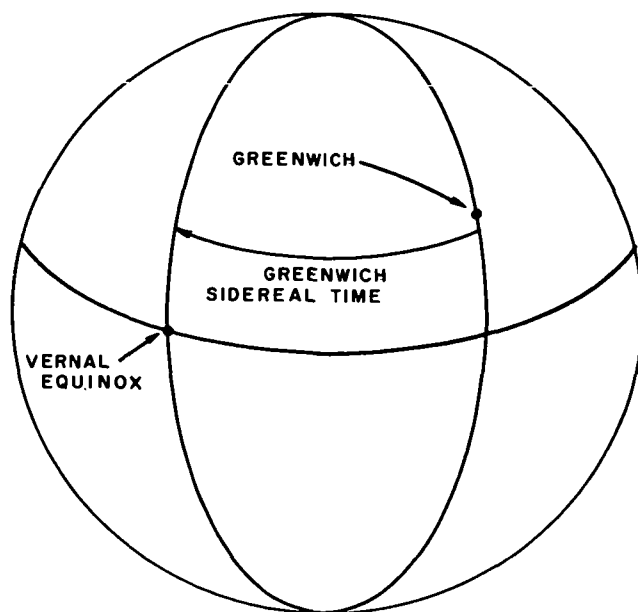


Figure 136. Greenwich sidereal time.

Greenwich mean time was $19^h 13^m 45^s$ on the 21st of July 1961, by adding $19^h 13^m 45^s$ (Greenwich mean time), $19^h 54^m 05^s$ (sidereal time at 0^h Greenwich mean time), and $3^m 10^s$ (correction of sidereal time at Greenwich mean time), the Greenwich sidereal time is $15^h 11^m 00^s$ ($39^h 11^m 00^s - 24^h$). All computations in artillery survey dealing with sidereal time are based on Greenwich sidereal time.

361. Greenwich Apparent Time

Greenwich apparent time (GAT) is the length of time that has elapsed since the sun last crossed the 180th meridian (fig. 137). Greenwich apparent time is determined by algebraically adding the equation of time for 0^h (GMT) and the correction for the partial day (GMT) to Greenwich mean time. Greenwich apparent time is used in artillery survey

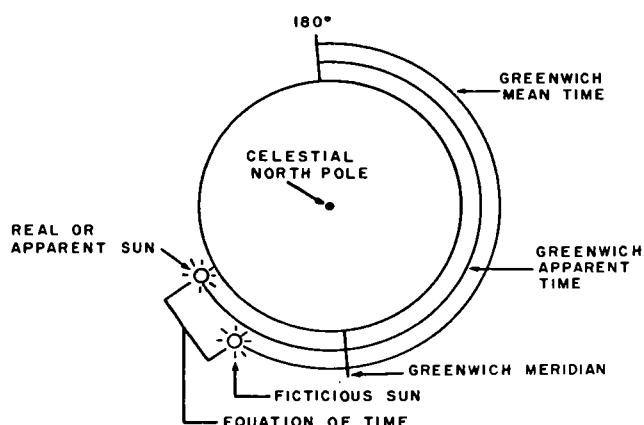


Figure 137. Greenwich apparent time.

astronomic computations for azimuth of the sun by the hour-angle method.

Section II. ASTRONOMIC TRIANGLE

362. General

Determination of azimuth by astronomic observations involves the solution of a spherical triangle visualized on the celestial sphere (fig. 138). The desired result of an astronomic observation, azimuth to the body, is determined by solving the triangle for the value of the azimuth angle. This value can be computed when certain other parts of the triangle are known. The triangle is called the astronomic triangle or the PZS triangle. The letters PZS stand for the three vertexes of the triangle; namely, the pole, the zenith, and the star (sun). The three sides of the triangle are the polar distance, the coaltitude, and the colatitude. The three angles are the parallactic angle, the azimuth angle, and the local hour angle.

363. Determining the Sides of the Triangle

To determine the sides of the astronomic triangle, certain basic factors covered in paragraphs 353 through 362 are applied.

a. *Polar Distance.* The declination of a celestial body is similar to latitude in that it is the angular distance north or south of the celestial equator measured along the hour circle of the celestial body, but, instead of giving it

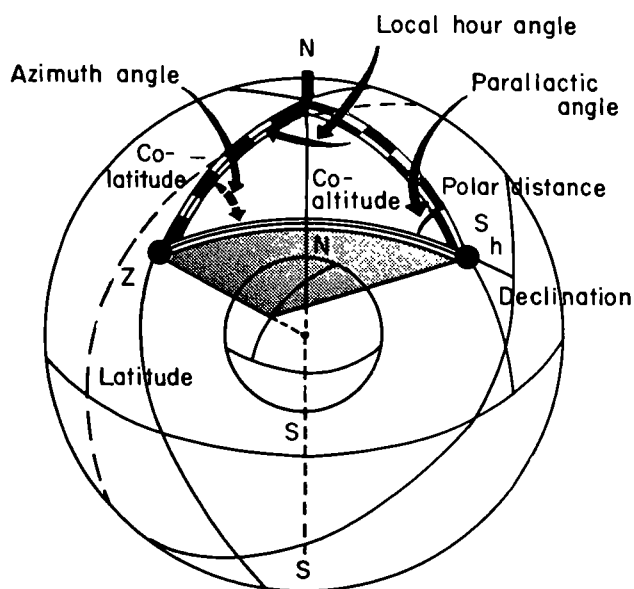


Figure 138. Celestial sphere with three sides and three angles of astronomic (PZS) triangle.

a value of north or south, it is given a positive (+) sign if it is north of the celestial equator and a negative (—) sign if it is south of the celestial equator. The angular distance from the equator to the pole being 90° , then the angular distance from the celestial body to the

pole (polar distance) is determined by algebraically subtracting the declination of the celestial body from 90° (fig. 138). For example, if the declination of the celestial body is $-13^\circ 06' 45''$, then the polar distance would be $90^\circ - (-13^\circ 06' 45'')$ or $103^\circ 06' 45''$.

b. Coaltitude. In order to determine the coaltitude side of the astronomic triangle, the corrected or true altitude must first be determined from the measured vertical angle to the celestial body by applying a correction for refraction (and for parallax for the sun only). Since the angular distance from the observer's horizon to the zenith is always 90° , the true altitude subtracted from this figure will give the coaltitude (fig. 138). For example, if the corrected altitude of a celestial body is $28^\circ 30'$, then the coaltitude would be $90^\circ - 28^\circ 30'$, or $61^\circ 30'$.

c. Colatitude. The latitude of the observer is the angular distance north or south of the equator along the observer's meridian. This same angular distance exists between the celestial equator and the zenith on the celestial sphere. The angular distance from the equator (celestial equator) to the pole (celestial pole) is 90° . The angular distance from the zenith to the pole (*colatitude*) is found by subtracting the latitude of the observer from 90° if the observer is in north latitude (fig. 138). For example, if the observer's latitude is $34^\circ 13' 30''$ N, the colatitude would be $90^\circ - 34^\circ 13' 30''$ or $55^\circ 46' 30''$. In south latitude, the colatitude is found by adding the latitude of the observer to 90° .

364. Determining the Angles of the Triangle

The angles of the astronomic triangle are determined as follows:

a. Parallax Angle. The parallax angle is the interior angle at the celestial body and is used in the formula for determining azimuth by the hour-angle method but cancels out in the computations.

b. Azimuth Angle. The azimuth angle is the interior angle of the astronomical triangle at the zenith and is sometimes referred to as the zenith angle. This angle is the product of computations and is used to determine the true azimuth to the celestial body from the observer. The angle can either be to the east or west of the observer's meridian, depending on whether the celestial body is east or west of the observer's meridian.

c. Local Hour Angle. The local hour angle is the interior angle of the astronomic triangle at the pole and is used only in hour-angle computations for azimuth. The local hour angle is determined in two ways, depending on whether the observation is made on the sun or on a star.

365. Examples of Determination of the Local Hour Angle

a. The local hour angle (LHA) for a star (figs. 139 and 140) is determined first by subtracting the right ascension of the star from Greenwich sidereal time which determines the Greenwich hour angle (GHA) (the time since the star last crossed the Greenwich meridian). The Greenwich hour angle is then converted into degrees, minutes, and seconds of arc, and

	Hours	Minutes	Seconds
LMT of observation -----	2	00	00
Correction for time zone -----	+ 6	00	00
GMT of observation -----	8	00	00
Sidereal time at 0 ^h GMT -----	+12	36	27
Corrections for sidereal time for GMT -----		1	19
GST of observation -----	20	37	46
RA of Altair for 1 April 1961 -----	-19	48	53
GHA of Altair at time of observation -----	0	48	53
	Degrees	Minutes	Seconds
GHA of Altair in arc -----	12	13	15
Longitude of observer (W) -----	(-) 94	39	14
LHA of observer -----	-82	25	59

the longitude of the observer is algebraically subtracted from the value of the angle, which gives the local hour angle. If the local hour angle is minus or less than 180° , this value is to be used in computations; if the value exceeds 180° and is less than 360° , the value to be used in computations is 360° minus the local hour angle; if the value above exceeds 360° , the value to be used in computations is the local hour angle minus 360° . For example, suppose that an observation is taken on Altair from longitude $94^\circ 39' 14''$ W at 0200 hours central standard time (CST) on 1 April 1961.

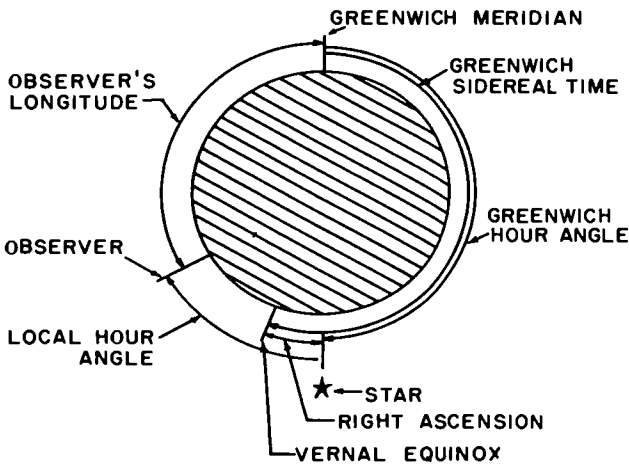


Figure 139. Determining the local hour angle (star) (observer in east longitude).

	Hours	Minutes	Seconds
LMT of observation -----	9	30	22
Correction for time zone ($73^\circ 19' 43''$ W) -----	+ 5	00	00
GMT of observation -----	14	30	22
Equation of time at 0^h (23 July 1961) -----	—	06	22
Correction for daily change for GMT -----	—		01
GAT of observation -----	14	23	59
	— 12	00	00
GHA of sun -----	2	23	59
	Degrees	Minutes	Seconds
GHA of sun in arc -----	35	59	45
Longitude of observer (W) -----	— 73	19	43
LHA of sun for observer -----	— 37	19	58

c. In both cases in *a* and *b* above, east longitude is understood to be minus and west longitude to be plus; therefore, in subtracting east longitude, it would mean algebraically sub-

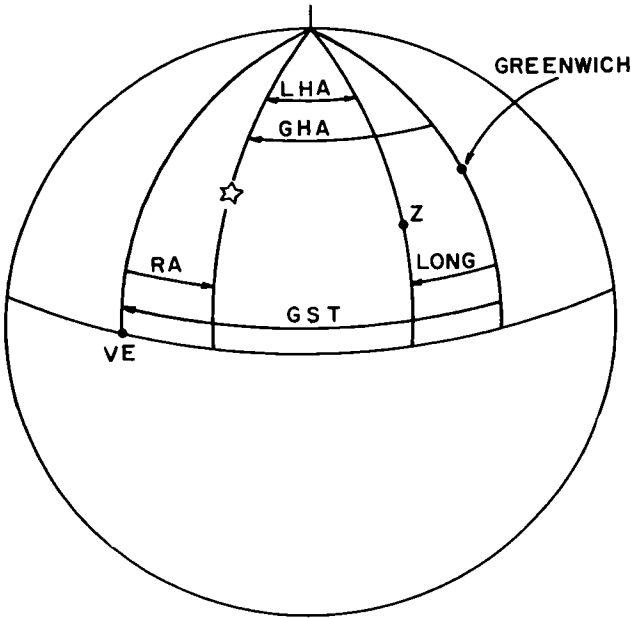


Figure 140. Determining the local hour angle (star) (observer in west longitude).

b. The local hour angle for observations on the sun is determined by subtracting the longitude of the observer from the Greenwich hour angle (which is Greenwich apparent time plus or minus 12 hours).

Example:

	Hours	Minutes	Seconds
LMT of observation -----	9	30	22
Correction for time zone ($73^\circ 19' 43''$ W) -----	+ 5	00	00
GMT of observation -----	14	30	22
Equation of time at 0^h (23 July 1961) -----	—	06	22
Correction for daily change for GMT -----	—		01
GAT of observation -----	14	23	59
	— 12	00	00
GHA of sun -----	2	23	59
	Degrees	Minutes	Seconds
GHA of sun in arc -----	35	59	45
Longitude of observer (W) -----	— 73	19	43
LHA of sun for observer -----	— 37	19	58

tracting a minus quantity or value. If the result is negative, the celestial body is east of the observer, and, if the result is positive, the celestial body is west of the observer.

366. Determining Azimuth in South Latitude

If the observer is in the Southern Hemisphere, there are different techniques for determining parts of the PZS triangle and the azimuth determined will be based on the south pole.

a. The coaltitude, the colatitude, and the local hour angle are determined in the same

manner as for the observer in the Northern Hemisphere.

b. The polar distance is determined by algebraically adding the declination of the celestial body to 90° with due regard to the algebraic sign of the declination.

c. The azimuth determined will be based on the south pole. The azimuth is corrected for convergence, and 180° is either added to or subtracted from the azimuth to determine the azimuth based on grid north.

Section III. STAR IDENTIFICATION

367. General

Astronomic observations for azimuth require that the personnel engaged in performing the fieldwork be capable of readily locating and identifying any of the stars listed in the Army Ephemeris, TM 6-300-61. These stars can be identified by using either (or both) of the two identification aids discussed in paragraphs 368 and 369.

368. Star Chart

The world star chart (fig. 141) based on the equator system shows most of the brighter stars in the heavens. All of the stars listed in TM 6-300-61 are shown as well as many others which aid the observer in locating these stars. The approximate right ascension and declination can be obtained from this chart and can be used as arguments to enter the chart.

369. Identification of Stars

a. Proficiency in star identification is usually based on a working knowledge of the constellations (star groups) and their relative locations. Starting with such familiar constellations as Orion (a kite-shaped figure on the celestial equator visible during the winter months), or Ursa Major (the Big Dipper), anyone should soon be able to lead himself from constellation to constellation across the sky. If, for example, one follows the arc of the Big Dipper on around, it will lead him directly to the star Arcturus and eventually to Spica in the constellation Virgo. Also, the end stars in the bucket of the Big Dipper (Dubhe and Merak, fig. 141) will lead the observer directly to Leo. These two stars are often referred to as the *pointers* since they are the most common

means used to locate Polaris, the North Star, when followed in the opposite direction from Leo. Figure 141, however, does not make this apparent because of distortion in the polar areas. Unfortunately, star charts, like maps, have to be printed on flat sheets of paper, and some of their relative positions are bound to be disturbed on the world star chart. Except for the stars near the celestial equator, the distortions on the world star chart are greater than they would be on a hemisphere star chart, but the world star chart is very useful because the declinations and right ascensions are shown graphically. The star chart indicates the relative position of the stars as viewed in the sky.

b. The first efforts should be concentrated on learning a half dozen stars in each 6 hours of the right ascension, which would be useful for observing on or near the prime vertical or as east and west stars. For instance, there are several stars just east of the constellation Orion forming a large pentagon with the α Canis Minor (Procyon) near the center. Greek letters were originally assigned in each constellation to the stars in order of the relative magnitude; these were only relative, but the α stars are nearly always bright and many of them have special names. The stars are rated in order of brightness from first magnitude to fifth or sixth, which are the dimmest that are ordinarily visible without a telescope. On the star chart, the magnitude is indicated by conventional signs, and it is also shown in TM 6-300-61. After learning the locations of Castor, Pollux, Regulus, Alphard, Sirius, and other stars in this part of the heavens, it is

easy to include others coming up from the east, as the night or season advances.

370. Star Identifier

The star identifier (fig. 142) based on the horizon system is issued to all artillery units that are issued a transit or a theodolite. It assists in locating stars by providing the approximate true azimuth and altitude to each given star. (It can also be used to identify stars of which the approximate true azimuth and altitude are known.) All stars shown on the star identifier are listed in the table, "Alphabetical Star List," in TM 6-300-61 and are shown in figure 141. The star identifier consists of a base and ten templates. Nine templates are used in star identification and one template with moon and planet data is not used in artillery survey. One side of the base, marked N is used in the Northern Hemisphere. The other side of the base, marked S is used in the Southern Hemisphere. A template is furnished for each 10° difference in latitude from 5° through 85°. One side of each template is used for the given latitude in the Northern Hemisphere. The other side is used for the same latitude in the Southern Hemisphere. The template constructed for the latitude nearest the latitude of the observer must be used. To use the star identifier—

a. Select the proper template and correctly place it on the appropriate side of the base.

b. Determine the orientation angle as follows:

- (1) Estimate the watch time at which the observations are to begin.
- (2) Determine the orientation angle, using DA Form 6-21 (par. 371).

c. Set the arrow on the template over the orientation angle.

d. Read the approximate true azimuth and the approximate altitude of any star on the base that is within the observer's field of vision (stars having altitudes between 20° and 45° and azimuths between 60° and 120° or between 240° and 300° should be selected).

e. Orient the star finder so that the pointer on the template is pointing approximately toward true south. The stars will then appear at the approximate altitudes read from the star finder; the approximate azimuth to the star is as read from the star finder in the Northern Hemisphere or equal to the azimuth read from the star finder minus 180° in the Southern Hemisphere.

371. Use of DA Form 6-21, Computation and Instructions for Use With Star Identifier

Figure 143 shows the entries made on DA Form 6-21 for determining data in finding and identifying stars. Instructions for the use of the form are contained on the reverse side of the form (fig. 144).

Figure 141. World star chart.

(Located in back of manual)

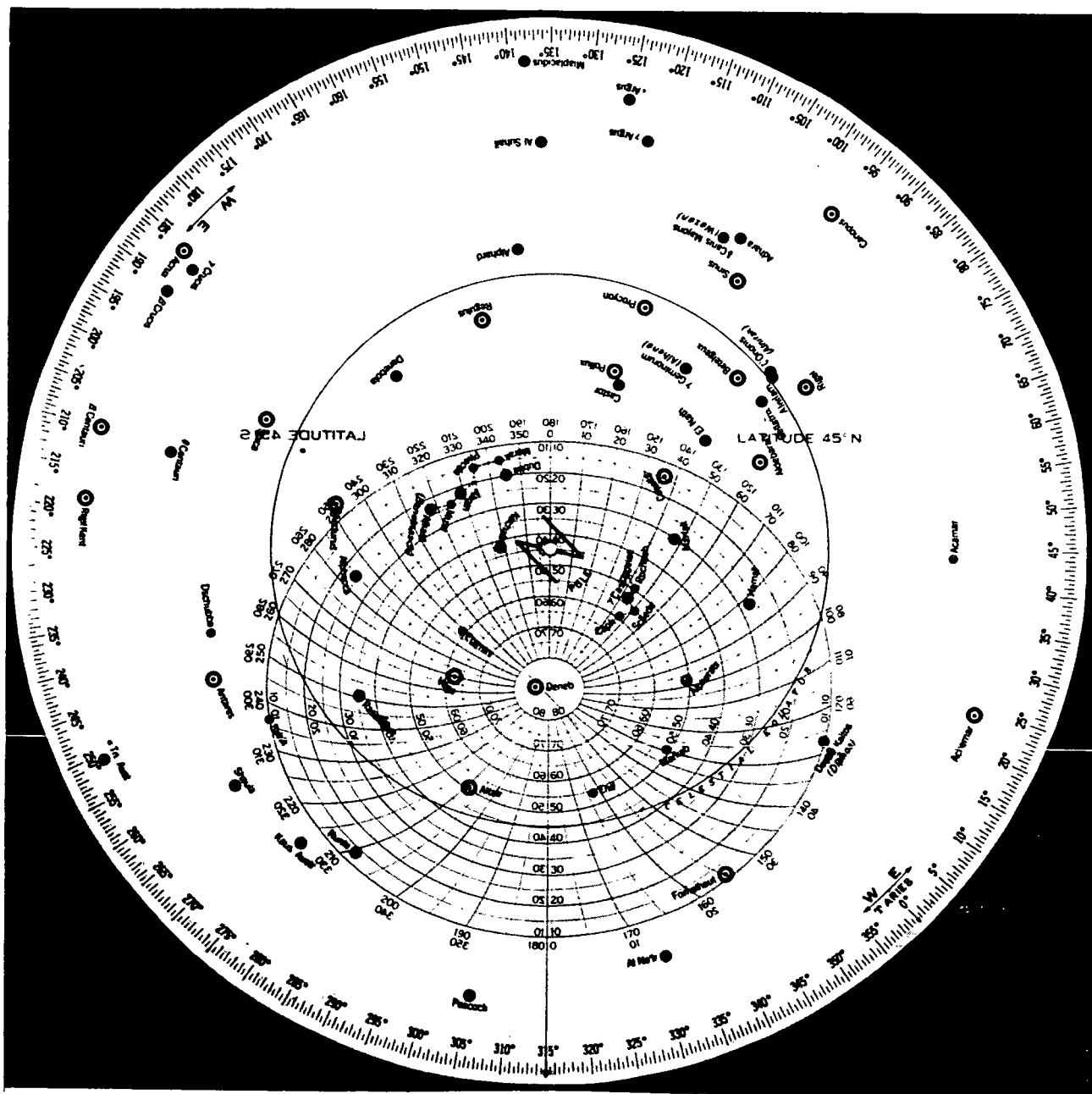


Figure 142. Star identifier.

COMPUTATION AND INSTRUCTIONS FOR USE WITH STAR IDENTIFIER (FD 6-120)											
TIME ZONE	S	LATITUDE OF STATION	34	LONGITUDE OF STATION	98°E	STATION	TS 19				
				SCHEDULE 1		SCHEDULE 3		SCHEDULE 3		SCHEDULE 4	
1	PRESELECTED LOCAL DATE			16 APR 61						1	
2	PRESELECTED WATCH TIME			2000						2	
3	LONGITUDE OF STATION			EAST +	98°					3	
4	LONGITUDE OF CENTRAL MERIDIAN (FROM TABLE I ON REVERSE)			EAST - WEST +	90°					4	
5	ALGEBRAIC SUM (3) AND (4)			8°						5	
6	SETTING FOR 0° ON LOCAL DATE (FROM TABLE II ON REVERSE)			204						6	
7	CORRECTION TO (4) FOR WATCH TIME (FROM TABLE III ON REVERSE)			301						7	
8	(6) + (7)			505		+		+		8	
9	REPEAT (3)			8		+		+		9	
10	ALGEBRAIC SUM (8) AND (9)			497		+		+		10	
11	ORIENTATION ANGLE			137						11	
SET POINTER OF APPROPRIATE TEMPLATE ON ORIENTATION ANGLE (SEE GUIDE ON REVERSE)											
13	NAME OF STAR			ALDEBARAN						13	
13	APRX AZIMUTH OF STAR			272°						13	
14	CONVERT (13) TO MILS, IF NECESSARY									14	
15	APRX ALTITUDE OF STAR			27°						15	
16	CONVERT (15) TO MILS, IF NECESSARY									16	
13	NAME OF STAR			BELLATRIX						13	
13	APRX AZIMUTH OF STAR			255°						13	
14	CONVERT (13) TO MILS, IF NECESSARY									14	
15	APRX ALTITUDE OF STAR			32°						15	
16	CONVERT (15) TO MILS, IF NECESSARY									16	
13	NAME OF STAR			BETELGEUSE						13	
13	APRX AZIMUTH OF STAR			251°						13	
14	CONVERT (13) TO MILS, IF NECESSARY									14	
15	APRX ALTITUDE OF STAR			38°						15	
16	CONVERT (15) TO MILS, IF NECESSARY									16	
13	NAME OF STAR			ARCTURUS						13	
13	APRX AZIMUTH OF STAR			81°						13	
14	CONVERT (13) TO MILS, IF NECESSARY									14	
15	APRX ALTITUDE OF STAR			23°						15	
16	CONVERT (15) TO MILS, IF NECESSARY									16	
COMPUTER		H. LINK			CHECKER		M. AFEE			SHEET 1 OF 1 SHEETS	

DA FORM 6-21
1 FEB 56

PREVIOUS EDITIONS OF THIS FORM ARE OBSOLETE.

Figure 143. Entries made on front of DA Form 6-21.

TABLE I		TABLE II														TABLE III	
TIME ZONE	LONG OF MERIDIAN	DAY OF MONTH	MONTH												DAY OF MONTH	WATCH TIME	CORR
EAST	LONG		JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC		0 ^h	0 ^o
Z	0°	1	100°	151°	158°	169°	216°	249°	278°	309°	341°	9°	40°	69°	1	1	15
A	15	2	101	152	159	190	219	280	379	510	341	10	41	70	2	2	30
R	30	3	102	153	160	191	220	251	280	511	342	11	42	71	3	3	45
C	45	4	103	154	161	192	221	252	281	512	343	12	43	72	4	4	60
D	60	5	104	155	162	193	222	253	282	513	344	13	44	73	5	5	75
E	75	6	105	156	163	194	223	254	283	514	345	14	45	74	6	6	90
F	90	7	106	157	164	195	224	255	284	515	346	15	46	75	7	7	105
G	105	8	107	157	165	196	225	256	285	516	347	16	47	76	8	8	120
H	120	9	108	158	166	197	226	257	286	517	348	17	48	77	9	9	135
I	135	10	109	159	167	198	227	258	287	518	349	18	49	78	10	10	150
K	150	11	110	160	168	199	228	259	288	519	350	19	50	79	11	11	165
L	165	12	111	161	169	200	229	260	289	520	351	20	51	80	12	12	180
M	180	13	112	162	170	201	230	261	290	521	352	21	52	81	13	13	195
WEST	LONG	14	113	163	171	202	231	262	291	522	353	22	53	82	14	14	210
Z	0°	15	114	164	172	203	232	263	292	523	354	23	54	83	15	15	225
M	15	16	115	165	173	204	233	264	293	524	355	24	55	84	16	16	240
O	30	17	116	166	174	205	234	265	294	525	356	25	56	85	17	17	255
P	45	18	117	167	175	206	235	266	295	526	357	26	57	86	18	18	270
Q	60	19	118	168	176	207	236	267	296	527	358	27	58	87	19	19	285
R	75	20	119	169	177	208	237	268	297	528	359	28	59	88	20	20	300
S	90	21	120	170	178	209	238	269	298	529	360	29	60	89	21	21	315
T	105	22	121	171	179	210	239	270	299	530	0	30	61	90	22	22	330
U	120	23	122	172	180	211	240	271	300	531	1	31	62	91	23	23	345
V	135	24	123	173	181	212	241	272	301	532	2	32	63	92	24	24	360
W	150	25	124	174	182	213	242	273	302	533	3	33	64	93	25	25	375
X	165	26	125	175	183	214	243	274	303	534	4	34	65	94	26	26	390
Y	180	27	126	176	184	215	244	275	304	535	5	35	66	95	27	27	405
		28	127	177	185	216	245	276	305	536	6	36	67	96	28	28	420
		29	128	178	186	217	246	277	306	537	7	37	68	97	29	29	435
		30	129	179	187	218	247	278	307	538	8	38	69	98	30	30	450
		31	130	180	188	219	248	279	308	539	9	39	70	99	31	31	465

GIVEN:

Time zone of area of operation.

Latitude and longitude of station to nearest degree.

Preselected local date of observation.

Preselected watch time of observation to nearest hour.

GUIDE:

When observation is to be made at other than preselected watch time ((2) of computation), increase orientation angle ((11) of computation) 1 degree for each 4 minutes of elapsed time after the hour or decrease orientation angle 1 degree for each 4 minutes of time before the hour.

Select stars between 20 and 45 degrees (60 degrees if a special eyepiece is available) above horizon and within 30 degrees of a 90-degree or 270-degree azimuth (east - west line) to use the altitude method.

Select four stars for each schedule, two in the east and two others in the west.

Read APRX AZIMUTH and APRX ALTITUDE of stars from template of star identifier to nearest degree.

When using a mil-graduated instrument, convert APRX AZIMUTH and APRX ALTITUDE to mils using table III b of TM 6-230.

LIMITATIONS:

The altitude and hour-angle methods should not be used when the star is more than 60 degrees above horizon.

RESULT:

APRX AZIMUTH and APRX ALTITUDE for four schedules of four stars each at preselected watch times.

Figure 144. Instructions for use of DA Form 6-21.

CHAPTER 22

THE ALTITUDE METHOD

Section I. GENERAL

372. General

The altitude method of astronomic observation requires the solution of the astronomic triangle for the value of the azimuth angle. The three sides of the triangle are used in the computations (polar distance, coaltitude, colatitude). The solution of this triangle has been simplified by the use of Department of the Army forms for the computations. The altitude method gets its name from the most critical element in the solution of the triangle—the corrected vertical angle to the celestial body or the true altitude.

373. True Altitude

In the solution of the altitude method of astronomic observations, the true altitude of the celestial body must be determined. The vertical angle to the celestial body can be determined by the observer but this is not the true altitude because the observer is located on the earth's surface and also because of the earth's atmosphere (*b* below). There are two corrections—parallax and refraction.

a. Parallax. Because the sun is so close to the earth, there is a difference between the vertical angle to the celestial body at the earth's surface and the vertical angle to the celestial body at the earth's center. This difference is called parallax and is equal to the angle at the center of the sun between the center of the earth and the observer. This difference is negligible on vertical angles to the stars because they are so far from the earth. The correction that is to be applied in artillery survey to the vertical angle observed on the sun is +07 seconds (0.04 mil); this is a mean value

and is always applied to altitude observations made on the sun.

b. Refraction. Owing to the density of the earth's atmosphere, a ray of light from space is bent downward to the earth as it passes through the atmosphere. Therefore, an observer on the earth sees the celestial body higher in the heavens than it actually is. The refraction correction varies according to the air temperature and the altitude of the celestial body observed. The refraction correction is always minus and is obtained from the ephemeris by using the air temperature at the station and the observed vertical angle to the celestial body.

374. Required Field Data

The field data which must be obtained to determine direction by the altitude method of astronomic observation are as follows:

- a.* Mean horizontal angle from an azimuth mark to the celestial body (sun or star).
- b.* Mean vertical angle to the celestial body.
- c.* Date and mean time of observation (correct to nearest 5 min).
- d.* Air temperature.
- e.* Geographic coordinates of station.
- f.* UTM (UPS) coordinates (whenever possible).
- g.* Approximate azimuth to the azimuth mark.

375. Selection of Astronomic Observation Station

When other survey operations do not determine the location of the point at which astronomic observations must be made, a point with known geographic coordinates should be se-

lected. If that is not possible, a point with known grid coordinates should be selected. If neither of these is possible, a point should be

selected which can easily be located on a large-scale map; i.e., a point which is easily identifiable both on the map and on the ground.

Section II. DETERMINING FIELD DATA

376. General

Field data for determining azimuth by astronomical observation consist of the horizontal angle between an azimuth mark and the observed celestial body, the vertical angle to the body (altitude method only), the time of the observation, the temperature at the time of the observation (altitude method only), and the location of the observing station in both geographic and grid coordinates.

377. Determining Horizontal and Vertical Angles

The instruments used to observe celestial bodies are the T16 theodolite or the T2 theodolite. Angles are determined in much the same manner as in any other method of survey; i.e., the angle is determined by comparing the mean pointing on one station with the mean pointing on another. Since celestial bodies appear to be moving, the technique of pointing is slightly modified. Also, since the sun presents such a large target, special techniques must be employed to determine its center.

378. Use of the T16 Theodolite in Astronomic Observations

a. The T16 theodolite is equipped with a solar circle on its reticle (fig. 145). This permits an observer to view the sun in such a manner that the vertical and horizontal crosslines of the instrument are directly over the center of the sun. The initial pointing on the azimuth mark is made with the telescope in the direct position. The telescope is then pointed toward the sun. The sun is placed in the solar circle and tracked by using both the horizontal and vertical tangent screws. When the sun is as nearly centered in the solar circle as possible, the observer announces TIP, levels the collimation level bubble, and reads the vertical and horizontal circle readings. The telescope is then plunged and the process repeated with the telescope in the reverse position. With the telescope still in the reverse position,

the final pointing is made on the azimuth mark, the mean data can now be determined.

Caution: Do not view the sun directly through the telescope unless the sun filter has been affixed to the eyepiece.

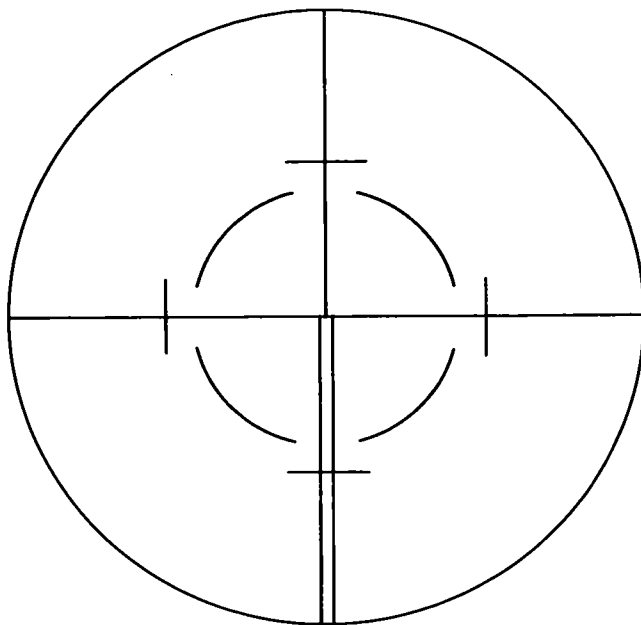


Figure 145. T16 theodolite reticle with solar circle.

b. Stellar observations with the T16 theodolite are performed as outlined in *a* above except that the intersection of the single vertical crossline and the horizontal crossline is used rather than the solar circle. This intersection is placed just ahead of the apparent path of the star. The star then moves into the intersection by its own apparent motion, at which time the operator announces TIP.

379. Use of the T2 Theodolite in Astronomic Observations

a. The T2 theodolite is not equipped with a solar circle for pointing on the center of the sun (fig. 146). To achieve measurements to

the center of the sun, measure the angles to one side of the sun with the telescope direct and then to the other side of the sun with the telescope in the reverse position. The resulting mean angle is the angle to the center of the sun. This method of determining the center of the sun is called the quadrant method and can be used either when the sun is viewed directly through a sun filter or when the image of the sun is projected onto a card held to the rear of the eyepiece of the telescope. To determine the correct quadrant in which to place the image of the sun, first determine the direction the sun is moving. If the motion of the sun is through the first and third quadrants (from first to third or from third to first) as viewed through the telescope or on the card, the image of the sun should be placed in the second and fourth quadrants. If the motion of the sun is through the second and fourth quadrants (from second to fourth or from fourth to second), the image of the sun should be placed in the first and third quadrants. The leading edge of the sun is always tracked with one of the crosslines and tangency is obtained with the other through the sun's movement. Pointings on the sun with the T2 theodolite are shown in figures 147 and 148. If the sun is placed tangent to the vertical crossline, it is brought into tangency with the slow horizontal

motion. If the sun is placed tangent to the horizontal crossline, it is brought into tangency with the slow vertical motion. Because of the double vertical crossline, the sun must be placed in one of the two quadrants separated by the single vertical crossline.

b. For stellar observations, the T2 theodolite is used in the same manner as discussed in paragraph 378b for the T16 theodolite.

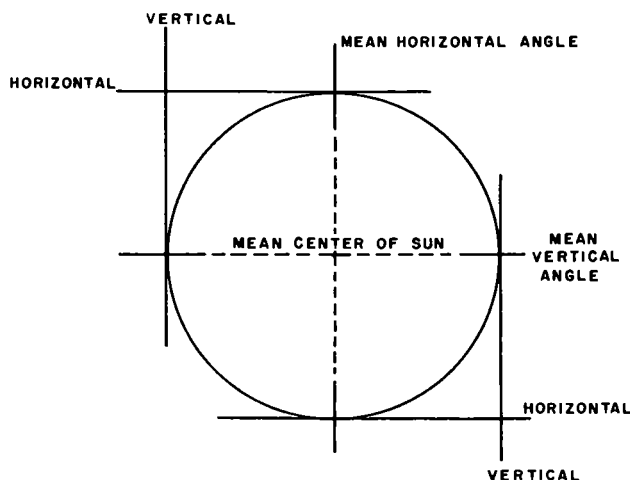


Figure 146. Method of observing to determine the mean center of the sun.

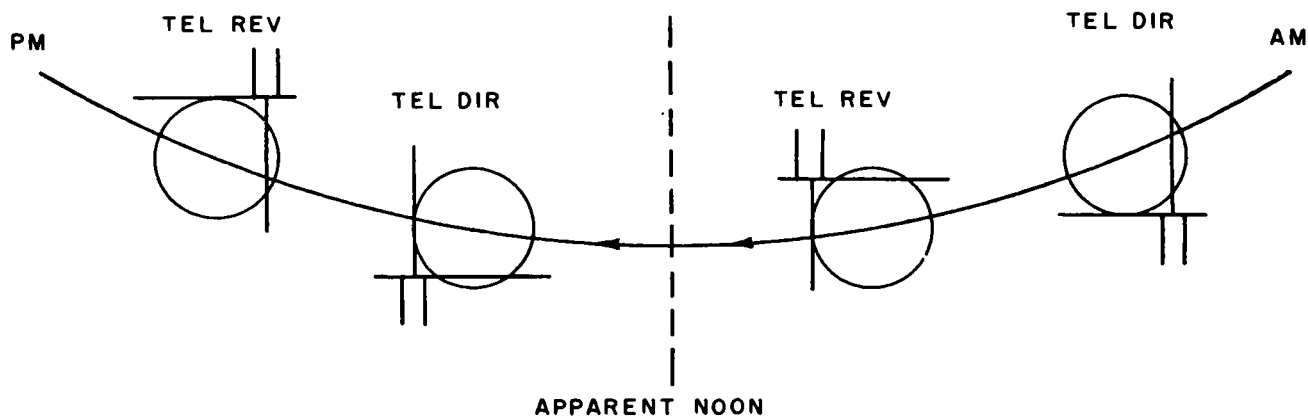


Figure 147. Quadrants used in Northern Hemisphere for observation with Wild T2 theodolite (direct observation with dark filter).

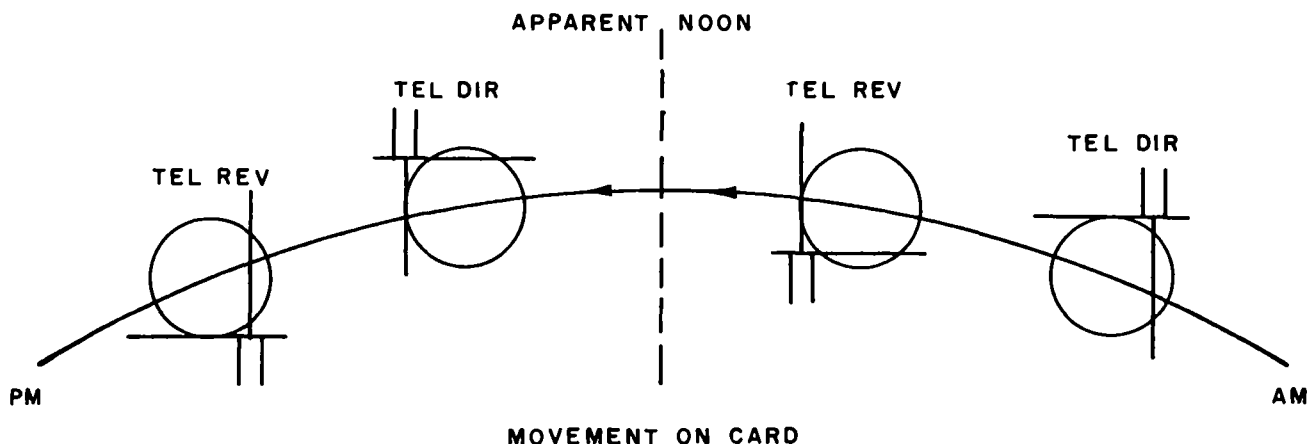


Figure 148. Quadrants used in Northern Hemisphere for observation with the Wild T2 theodolite (card method).

380. Time

a. The times at which pointings are made on the sun or a star are read and recorded to the nearest second for both methods of astronomic observation. With the altitude method, it is not necessary to know time to this accuracy, but recording the time to the nearest second will give the recorder additional practice in reading and recording time for the hour-angle method. *Time recorded to the nearest second will also provide survey personnel a means for detecting errors from examination of field data.* When the altitude method is used for observing a star, it is necessary to know only the date of observation. When the altitude method is used for observing the sun,

it is necessary to know only the date and time of observation with an error of not more than 5 minutes. Time correct to 5 minutes can be obtained from the message center clock.

b. The watch used by the artillery surveyor to measure time for astronomic observations should be a reliable watch with a sweep second hand.

c. Watch times are based on standard time zones, each of which covers a portion of the earth. In a zone of operations, survey personnel using astronomic observations must know the time zone on which their watch time is based. The time zone on which a watch is based can be determined from the message center. (Time zone corrections are given in table I.)

Table I. Time Zone Corrections, Local Mean Time to Greenwich Mean Time

Time Zone	Correction (hours)	Time Zone	Correction (hours)
Z -----	0	Z -----	0
A -----	- 1	N -----	+ 1
B -----	- 2	O -----	+ 2
C -----	- 3	P -----	+ 3
D -----	- 4	Q -----	+ 4
E -----	- 5	R -----	+ 5
F -----	- 6	S -----	+ 6
G -----	- 7	T -----	+ 7
H -----	- 8	U -----	+ 8
I -----	- 9	V -----	+ 9
K -----	-10	W -----	+10
L -----	-11	X -----	+11
M -----	-12	Y -----	+12

Note. Time zone Q corresponds to eastern daylight saving time. Time zone R corresponds to eastern standard time and central daylight saving time. Time zone S corresponds to central standard time and to mountain daylight saving time. Time zone T corresponds to mountain standard time and to Pacific daylight saving time. Time zone U corresponds to Pacific standard time.

381. Time of Observation

Because of the apparent motion of a celestial body, the watch time at which each pointing is made on the celestial body should be read and recorded to the nearest second. To obtain the accurate time of observation the instrument operator announces "*Ready*" a few seconds before the star is at the intersection of the crosshairs or before the sun is tangent to the crosshairs. He announces "*Tip*" and stops tracking at the exact instant of tangency. The recorder reads and records the time corresponding to the exact second that the operator announces "*Tip*." The times corresponding to the direct (first) reading and the reverse (second) reading are meaned. This is the mean time of observation.

382. Temperature

For the altitude method, it is necessary to know the air temperature at the time of observations in order to determine a refraction correction. The temperature should be determined within an accuracy of 5° F. The temperature can be determined by using the psychrometer in a surveying altimeter, or it can be obtained, by prior arrangement, from a meteorological or weather section. In an artillery unit, the temperature can be obtained from the thermometer used to obtain powder temperature in a gun section.

383. Geographic Coordinates of the Astronomic Observation Station

The geographic coordinates (latitude and longitude) of the astronomic observation station must be known for the hour-angle method. The latitude of the station must be known for the altitude method. For both methods, it is desirable to know the geographic coordinates for the computation of convergence. (The geographic coordinates of trig points can usually be obtained from trig lists issued by the Corps of Engineers.)

a. If the geographic coordinates of the station are not known, they are determined, if possible, by measuring, from a large-scale map. If the grid coordinates of the station are known, they should be used to accurately plot the location of the station on the map. If the

grid coordinates of the station are not known, the location of the station must be plotted on the map by *careful map inspection*.

b. If the geographic coordinates of the station are not known and a large-scale map is not available but the accurate grid coordinates are known, the geographic coordinates must be determined by conversion of the grid coordinates (ch. 27).

c. If the geographic coordinates cannot be determined by any means, azimuth cannot be determined by the altitude or hour-angle method of astronomic observation.

384. UTM Grid Coordinates of the Astronomic Observation Station

The UTM grid coordinates of the astronomic observation station should be known in order to compute convergence through both geographic and UTM grid coordinates.

385. Approximate Azimuth to Azimuth Mark

The approximate azimuth to the azimuth mark should be determined and recorded to detect large errors in computations. This azimuth may be determined by using an M2 compass or the compass of an aiming circle or by scaling the azimuth from a large-scale map.

386. Recording Field Data

Field data for astronomic observations are recorded as discussed in paragraph 206.

387. Determination of Final Azimuth

a. Fifth-order astronomic azimuths are determined by using the T16 theodolite. To achieve a fifth-order astronomic azimuth, observe and compute at least three sets of observations—each set, one position. Mean the azimuths and reject any set which varies from the mean by more than 0.3 mil. At least two sets must remain and be remeaned to determine final azimuth. The considered accuracy of a fifth-order astronomic observation is ± 0.3 mil.

b. Fourth-order astronomic azimuths are determined by using the T2 theodolite. To achieve a fourth-order astronomic azimuth, observe and compute at least three sets of obser-

uations—each set one position. Mean the azimuths and reject any set which varies from the mean by more than 30". At least two sets must remain and be remeaned to determine final azimuth. The considered accuracy of a fourth-order astronomic observation is $\pm 30''$.

388. Azimuth Checks and Improvements

Azimuths may be checked and improved by using the following methods:

a. A final azimuth determined from observations on the sun before noon may be checked and improved by determining another final azimuth on the sun in the afternoon. The same observer's position and azimuth mark are used. The two final azimuths are meaned.

b. Another method of improving or checking an azimuth is to use *an east and a west star* and mean the final azimuths.

389. Limitations

a. For best results with the altitude method, the celestial body is observed within 30° (azimuth) of the prime vertical (60° to 120° and 240° to 300° in azimuth). The vertical angle is the critical element in the altitude method but an error in vertical angle has less effect on the final azimuth throughout this band. A celestial body should not be observed at altitudes less than 20° because the refraction correction is very great.

b. Vertical angles of less than 20° have a large and uncertain refraction correction. (A 5° vertical angle at 80° F. has a refraction correction of 9' 06".) Refraction corrections for vertical angles less than 20° are not tabulated in TM 6-300-61. Do not attempt to observe a celestial body above 45° without special astronomical equipment.

Section III. COMPUTATIONS

390. Computation of Astronomic Azimuth

Computations for determination of astronomic azimuth by the altitude method are entered on DA Form 6-11 (Computation-Astronomic Azimuth by Altitude Method, Sun or Star (figs. 149 and 150)). This astronomic azimuth can be converted to grid azimuth by using DA Form 6-20 (Computation-Convergence (figs. 151 and 152) (par. 392)).

391. Use of DA Form 6-11

a. Determination of azimuth by the altitude method depends on solution of the astronomic (PZS) triangle when the three sides—polar distance, colatitude, and coaltitude—are known (par. 363). DA Form 6-11 provides a convenient step-by-step means for computing the azimuth angle (par. 364b) required. The horizontal angle measured from the azimuth mark to the celestial body observed is applied to the computed azimuth during the last steps to determine true azimuth to the mark. The formula solved and a guide for use of the form are shown on the back of the form.

b. Entries are made on the form as shown in figures 149 and 150. The data given below are taken from the field notes.

(1) *Station.* BnSCP.

(2) *Azimuth mark.* Station Oak.

(3) *Latitude.* 30° 16' 21" N.

(4) *Longitude.* 97° 36' 42" W.

(5) *Area.* Round Hill.

(6) *Approximate azimuth to the azimuth mark.* 3650 mils.

(7) *Local date.* 29 May 1961.

(8) *Temperature.* 94° F.

(9) *Watch correction.* 13 seconds slow (+13^s).

(10) *Mean time of observation.* 15^h 22^m 12^s (S).

(11) *Mean vertical angle.* 477.3 mils.

(12) *Mean horizontal angle.* 954.8 mils.

c. Under certain conditions, auxiliary computations are required to determine data for entry on DA Form 6-11. Spaces for these computations are provided on the reverse side of the form.

(1) When observations are made with a mil-graduated instrument, latitude and longitude of the observation station are converted to mils in the space provided.

(2) When the sun is the celestial body observed, an auxiliary computation for declination at Greenwich mean time of observation is necessary to

COMPUTATION - ASTRONOMIC AZIMUTH BY ALTITUDE METHOD, SUN OR STAR										TABLE NOS REFER TO TM 6-300-19 <u>61</u>		SUN OR STAR NAME AND NR (TABLE 9) <u>SUN</u>																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																												
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17	(15) + (16)	16	91	34																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																				
18	LATITUDE (17) OF CONVERSION TO MILS NORTH + SOUTH -	5	38	17																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																				
19	ALGEBRAIC SUM (17) AND (18)	22	29	51							Sketch showing Sun, Station, and Azimuth North arrow.																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																													
20	1/2 OF (19)	11	14	76																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																				
21	REPEAT (15)	12	14	52																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																				
22	SUBTRACT SMALLER, (20) OR (21), FROM LARGER, (21) OR (20), SIGN ALWAYS PLUS	11	14	76																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																				
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29 MAY 1961

ROUND BILL

AREA

4-B-6

HYPERION

DA FORM 6-11
1 DEC 55

REPLACES EDITION OF 1 SEP 55, WHICH IS OBSOLETE

Figure 149. Entries made on front of DA Form 6-11 for computing true azimuth from observations on the sun (altitude method).

AUXILIARY COMPUTATION FOR APPARENT DECLINATION OF SUN AT GREENWICH DATE AND GMT									
		SET HR _____		SET HR _____		SET HR _____			
1	GREENWICH DATE (16) OF COMPUTATION	29 MAY 61							
2	GMT (HOURS AND MINUTES IN 16) OF COMPUTATION	HRS 21	MIN 22	HRS X60	MIN X60	HRS X60	MIN X60		
3	NUMBERS OF HOURS IN (2) X 60	1260							
4	NUMBER OF MINUTES IN (2)	22							
5	(3)+(4)	1282							
6	DAILY CHANGE IN DECLINATION (TABLE 2)	⊕ 2 75		±		±			
7	LOG OF (5)	3. 107 888							
8	LOG OF (6)	0. 439 333							
9	LOG OF CONSTANT	6. 8 41 6375		6. 8 41 6375		6. 8 41 6375			
10	(7)+(8)+(9)	0. 388 8585							
11	NUMBER HAVING LOG (10) ± SECONDS OR MILS OF CHANGE	2 45							
12	APPARENT DECLINATION AT 0° ON GREENWICH DATE (TABLE 3)	⊕ 3 83 03 ±							
13	(11) CONVERTED TO MINUTES AND SECONDS OR (11) IN MILS (USE SIGN OF (6))	⊕ 2 45 ±							
14	ALGEBRAIC SUM (12) AND (13) ENTER IN (12) ON FRONT	⊕ 3 85 48 ±							
CONVERSION TO MILS COMPUTATION (USE TABLE III b OF TM 6-230)									
1	LONGITUDE (FROM FRONT OF FORM)	97° 36' 42"		10	LATITUDE (FROM FRONT OF FORM)	30° 16' 21"			
2	IN HUNDREDS OF DEGREES OF (1)	-- -- --		11	IN TENS OF DEGREES OF (10)	5 33 33			
3	IN TENS OF DEGREES OF (1)	16 00 00		12	IN UNITS OF DEGREES OF (10)	-- -- --			
4	IN UNITS OF DEGREES OF (1)	1 24 44		13	IN TENS OF MINUTES OF (10)	2 96			
5	IN TENS OF MINUTES OF (1)	8 89		14	IN UNITS OF MINUTES OF (10)	1 78			
6	IN UNITS OF MINUTES OF (1)	1 78		15	IN TENS OF SECONDS OF (10)	10			
7	IN TENS OF SECONDS OF (1)	20		16	IN UNITS OF SECONDS OF (10)	00			
8	IN UNITS OF SECONDS OF (1)	01		17	SUM OF (11) THROUGH (16) [ENTER IN (18) ON FRONT AND ON DA FORM 6-20]	5 38 17			
9	SUM OF (2) THROUGH (8) [ENTER ON DA FORM 6-20]	17 35 32							

GIVEN:

Time zone of area of operation.

FIELD DATA:

Latitude and longitude of station.

Approximate azimuth to azimuth mark and to sun or star (sketch).

Sun or name(s) and number(s) of selected star(s).

Local date of observation.

Temperature at time of observation.

Mean watch time of observation and watch correction.

Horizontal clockwise angle from azimuth mark to sun.

Observed altitude of (vertical angle to) sun or star.

GUIDE:

Enter observed field data in block marked.

When using a mil-graduated instrument, --

a. (7) through (22) of computation are computed using hundredth-mil values.

b. (6) through (14) of AUXILIARY COMPUTATION are computed using hundredth-mil values.

c. (2) through (9) and (11) through (17) of CONVERSION TO MILS COMPUTATION are computed using hundredth-mil values.

d. (23) through (37) of computation are computed using tenth-mil values.

Value in (37) should be about equal to approximate azimuth to azimuth mark.

Continue computations using DA Form 6-20 to obtain the UTM grid azimuth.

LIMITATIONS:

This form should not be used when accuracies greater than fourth-order are required.

The altitude method should not be used when the sun or star is --

a. Less than 20 degrees or more than 60 degrees above horizon.

b. More than 30 degrees from a 90-degree or 270-degree azimuth (east-west line).

RESULTS:

A value of astronomic azimuth for each set of observations.

FORMULA:

$$\cos 1/2 A = \frac{\cos s \cos (s-p)}{\cos \text{Lat} \cos h}$$

A = astronomic azimuth of sun or star measured east or west of meridian.

s = 1/2 sum of polar distance, latitude, and true altitude.

p = polar distance of celestial body.

Lat = latitude of station.

h = true altitude of celestial body.

Figure 150. Auxiliary computations and instructions on back of DA Form 6-11.

determine the value to be entered on line 12 of DA Form 6-11. The Army Ephemeris (table 2) tabulates data for declination of the sun at 0^h GMT for each day of the year and the daily change from one day to the next. An interpolation is performed to determine the fraction of daily change corresponding to the difference between 0^h GMT and GMT of observation. A space is provided on the reverse side of the form for this interpolation. The following formula is solved:

$$\frac{\text{Change in declination} = \text{GMT of observation} \times \text{daily change (seconds or mils)}}{1,440 \text{ (minutes in a day)}}$$

392. Use of DA Form 6-20

a. Computation for determining the convergence (difference between grid north and true

north) for the observer's location is performed on DA Form 6-20 (figs. 151 and 152) from geographic and, if possible, from grid coordinates. This convergence is algebraically added to the astronomic (true) azimuth computed on DA Forms 6-10, 6-10a, and 6-11 to convert that azimuth to grid azimuth.

b. The data necessary to compute the convergence are the geographic and grid coordinates of the observer's location. The convergence for the problem computed in figures 151 and 152 is computed from the following data:

- (1) *Station.* BnSCP.
- (2) *Azimuth mark.* Station Oak.
- (3) *Latitude.* 30° 16' 21" N.
- (4) *Longitude.* 97° 36' 42" W.
- (5) *UTM grid coordinates (nearest 100 meters).* (633600-3349600).

COMPUTATION - CONVERGENCE (ASTRONOMIC AZIMUTH TO UTM GRID AZIMUTH)									
(Table Numbers Refer to TM 6-300- 19 61)									
(FM 6-120)									
STATION Bn SCP					AZIMUTH MARK STATION OAK				
LONGITUDE OF STATION			17 35 32		UTM GRID ZONE		EASTING OF STATION		
LATITUDE OF STATION			5 38 17		NORTHING OF STATION		3 349 600		
1 LONGITUDE OF STATION					17 35 32		11 EASTING OF STATION		
3 LONGITUDE OF CENTRAL MERIDIAN (FROM TABLE ON REVERSE)					17 60 00		12 500 000		
IF (1) IS: (2) IS:					17 35 32		IF (11) IS: (12) IS:		
MORE THAN (2) (1) - (2)							MORE THAN (12) (11) - (12)		
LESS THAN (2) (2) - (1)					24 68		LESS THAN (12) (12) - (11)		
4 IF (1) IS IN DEGREES, USE (8) OF CONVERSION COMP ON REVERSE					24 68		14 REPEAT (13) WITH DECIMAL POINT MOVED LEFT SIX PLACES		
IF (1) IS IN MILS, REPEAT (3)							0.133 600		
5 LOG (4)					1.392 345		15 LOG (14)		
6 LOG SIN LATITUDE OF STATION					9.702 544		16 LOG OF FUNCTION XV (TABLE 6) (18874)		
7 (5) + (6)					1.094 889		17 (15) + (16)		
8 NUMBER HAVING LOG (7) = FIRST TERM IN SECONDS OR MILS					12.44		18 LOG CONVERSION SECONDS TO MILS		
9 SECOND TERM (TABLE 8 OR 8-MILS, USE (2) AND LATITUDE)					0.00		19 IF (1) IS IN DEGREES, REPEAT (17) IF (1) IS IN MILS, USE (17) + (18)		
(8) + (9) = CONVERGENCE IN SECONDS OR MILS WHEN STATION IS IN NORTH LATITUDE AND... IF (1) IS: (10) IS: (10) IS: MORE THAN (2) + LESS THAN (2) - WHEN STATION IS IN SOUTH LATITUDE AND... IF (1) IS: (10) IS: (10) IS: MORE THAN (2) - LESS THAN (2) +					12.44		20 NUMBER HAVING LOG (19) = FIRST TERM IN SECONDS OR MILS		
							12.45		
							21 SECOND TERM (TABLE 7, USE (11) AND NORTHING)		
							0.00		
							(20) - (21) = CONVERGENCE IN SECONDS OR MILS WHEN STATION IS IN NORTH LATITUDE IF (11) IS: (22) IS: MORE THAN (12) - LESS THAN (12) + WHEN STATION IS IN SOUTH LATITUDE IF (11) IS: (22) IS: MORE THAN (12) + LESS THAN (12) -		
							22 12.45		
IF (10) AND (22) DIFFER BY MORE THAN { 04" } REDETERMINE COORDINATES AND RECOMPUTE ALL COMPUTATIONS									
					23 CONVERGENCE		IF (1) IS IN DEGREES, USE (18) OF CONVERSION COMP ON REVERSE IF (1) IS IN MILS, REPEAT (22)		
							+ 12.45		
SUMMARY OF ASTRONOMIC AZIMUTHS AND COMPUTATION OF UTM GRID AZIMUTH									
		ASTRONOMIC AZIMUTH TO AZIMUTH MARK				REMARKS			
24	SET NR 1	40 33 8							
25	SET NR 3								
26	SET NR 2								
27	SET NR								
28	SET NR								
29	SET NR								
30	SUM	40 33 8							
31	MEAN (SIGN +)	+ 40 33 8							
22	CONVERGENCE REPEAT (23)	+ 12 4							
33	ALGEBRAIC SUM OF (21) AND (32) = GRID AZIMUTH TO MARK	40 21 4							
COMPUTER SMITH					CHECKER JONES				
NOTEBOOK REFERENCE 4-B-6		AREA ROUND HILL			DATE 29 MAY 1961				
SHEET 1 OF 1 SHEETS									

Figure 151. Entries made on front of DA Form 6-20 for converting true azimuth to correct grid azimuth.

TABLE - CENTRAL MERIDIAN OF UTM GRID ZONES

ZONE NR	DEGREES W LONG	MILS W LONG	ZONE NR	DEGREES W LONG	MILS W LONG	ZONE NR	DEGREES E LONG	MILS E LONG	ZONE NR	DEGREES E LONG	MILS E LONG
1	177	3146.67	16	87	1546.67	31	3	53.33	46	93	1553.33
2	171	3040.00	17	81	1440.00	32	9	160.00	47	99	1766.00
3	165	2933.33	18	75	1333.33	33	15	266.67	48	105	1866.67
4	159	2826.67	19	69	1226.67	34	21	373.33	49	111	1973.33
5	153	2720.00	20	63	1120.00	35	27	480.00	50	117	2080.00
6	147	2613.33	21	57	1013.33	36	33	586.67	51	123	2186.67
7	141	2506.67	22	51	906.67	37	39	693.33	52	129	2293.33
8	135	2400.00	23	45	800.00	38	45	800.00	53	135	2400.00
9	129	2293.33	24	39	693.33	39	51	906.67	54	141	2506.67
10	123	2186.67	25	33	586.67	40	57	1013.33	55	147	2613.33
11	117	2080.00	26	27	480.00	41	63	1120.00	56	153	2720.00
12	111	1973.33	27	21	373.33	42	69	1226.67	57	159	2826.67
13	105	1866.67	28	15	266.67	43	75	1333.33	58	165	2933.33
14	99	1760.00	29	9	160.00	44	81	1440.00	59	171	3040.00
15	93	1653.33	30	3	53.33	45	87	1546.67	60	177	3146.67

CONVERSION COMPUTATION

DEGREES, MINUTES, AND SECONDS TO SECONDS				SECONDS TO DEGREES, MINUTES, AND SECONDS			
1	REPEAT (3)			9	REPEAT (22) OF COMPUTATION		
2	NUMBER OF DEGREES IN (1)			10	NUMBER OF TIMES 3600 DIVIDES INTO (9) = NUMBER OF DEGREES IN (9)		
		X 60		11	REPEAT (9)		
3	(2) X 60			12	NUMBER IN (10) X 3600		
4	NUMBER OF MINUTES IN (1)			13	(11) - (12)		
5	(3) + (4)			14	NUMBER OF TIMES 60 DIVIDES INTO (13) = NUMBER OF MINUTES IN (9)		
		X 60		15	REPEAT (13)		
6	(5) X 60			16	NUMBER IN (14) X 60		
7	NUMBER OF SECONDS IN (1)			17	(15) - (16) = NUMBER OF SECONDS IN (9)		
8	(6) + (7) ENTER IN (4) ON FRONT			18	(10) + (14) + (17) = CONVERGENCE (ENTER IN (23) ON FRONT)		

GIVEN:

UTM grid zone of area of operation.
 UTM grid coordinates of station to nearest meter.
 Latitude and longitude of station to nearest second or one-hundredth mil (DA Form 6-10, 6-10a, or 6-11).
 A value of astronomic azimuth for each set of observations (DA Form 6-10, 6-10a, or 6-11).

GUIDE:

When using a mil-graduated instrument, - -
 a. (1) through (5), (7) through (10), and (20) through (22) of computation are computed using hundredth-mil values.
 b. (6) and (24) through (33) of computation are computed using tenth-mil values.
 Compare (10) and (22) and, if they differ by more than 4 seconds or 0.02 mils, redetermine coordinates and recompute all computations.

LIMITATIONS:

This form should not be used when accuracies greater than third-order are required.

RESULTS:

A value of UTM grid azimuth from the mean values of astronomic azimuth and the grid convergence at the station.

FORMULAS:

UTM grid azimuth = Astronomic azimuth + convergence.

USING UTM GRID COORDINATES:

$$\text{Convergence} = (XV)q - (XV)q^3$$

(XV) = a variable function based on latitude of station (obtained from TM 6-300-19, "Army Ephemeris for 19__").

q = 0.000 001 times the distance in meters from central meridian of UTM grid zone to station.

(XV)q³ = second term of convergence computation (obtained from TM 6-300-19, "Army Ephemeris for 19__").

USING GEOGRAPHIC COORDINATES:

$$\text{Convergence} = (XII)p + (XIII)p^3$$

(XII) = 10,000 times sine of latitude of station.

p = 0.0001 times distance in seconds or mils of arc from central meridian of UTM grid zone to station.

(XIII)p³ = second term of convergence computation (obtained from TM 6-300-19, "Army Ephemeris for 19__").

Figure 152. Auxiliary computations and instructions on back of DA Form 6-20.

CHAPTER 23

HOOR-ANGLE METHOD

Section I. GENERAL

393. General

a. The hour-angle method of astronomic observation also requires the solution of the astronomic triangle. The parts of the triangle that are used are the polar distance, the colatitude, and the local hour angle (two sides and the included angle).

b. The local hour angle is determined from the time of observation and is directly proportional to the azimuth of the body; therefore, it is extremely important that it be correct to the nearest 1 second. The hour-angle method can be used any time the altitude method is used, provided time is correct to the nearest second.

c. The hour-angle method can be used when the celestial body is below 20° altitude; however, as the line of sight approaches the observer's horizon, an error (horizontal refraction) may be introduced which cannot be corrected.

d. If there is no celestial body within the

desirable limits for the altitude method, then a celestial body which is as near as possible to the limits should be selected and the hour-angle method used.

394. Required Field Data

a. The field data required for the hour-angle method are slightly less than the altitude method. The data needed to compute the azimuth by the hour-angle method are as follows:

- (1) Mean horizontal angle from azimuth mark to celestial body.
- (2) Mean time of observation correct to nearest second (10^s for Polaris).
- (3) Geographic coordinates of observer's station and when possible UTM (UPS) grid coordinates to nearest 100 meters.
- (4) Approximate azimuth to azimuth mark.

b. The vertical angle is not needed for the hour-angle method.

Section II. DETERMINING FIELD DATA

395. Determining Angles (Hour-Angle Method)

Except for the method of pointings (pars. 379 and 380) horizontal angles are determined for the hour-angle method in the same way that they are determined for the altitude method. (A set of observations for the hour-angle method consists of determining horizontal angles—one position for theodolites.)

396. Pointings on Celestial Bodies (Hour-Angle Method)

The techniques of pointing for the altitude

method (pars. 379 and 380) may be used for the hour-angle method. Alternate methods of pointing for the hour-angle method are given in paragraphs 398 and 399.

397. Pointings on a Star (Hour-Angle Method)

When observing a star for the hour-angle method, place the vertical crossline just ahead of the star so that the star will move toward the crossline. Place the horizontal crossline approximately on the star. Let the crosslines

remain stationary. Just before the vertical crossline is over the star, announce "*Ready*". At the instant that the crossline is over the star, announce "*Tip*". (The recorder reads and records the watch time corresponding to the exact instant that the instrument operator announces "*Tip*".)

398. Pointings on the Sun (Hour-Angle Method)

When observations are made with the T16 theodolite, the procedures for pointings on the sun are as described in paragraph 379a. When the T2 theodolite is used, either the quadrant method discussed in paragraph 380 or the following procedures are used: Place the vertical crossline just ahead of the leading edge of the sun in the direct position and just ahead of the trailing edge of the sun in the reverse position so that the sun will move into tangency with the vertical crossline. Place the horizontal crossline so that it approximately bisects the sun. Let the crosslines remain stationary. Just before tangency, the observer announces "*Ready*". At the instant of tangency, he announces "*Tip*". (The recorder reads and records the watch time corresponding to the exact instant the observer announces "*Tip*".) Using this method, obtain tangency first with the leading edge of the sun (telescope direct) and then with the trailing edge of the sun (telescope reversed).

399. Time

When the hour-angle method is used, the time is not only recorded to the nearest second, but it must be correct to the nearest second (nearest 10 seconds for Polaris). The method for obtaining the correct time from radio time signals is explained in detail in TM 5-234. The watch correction should be obtained before and after the observations. If there is a difference, the mean time of each observation must be determined by using the corrections.

400. Coordinates

The methods of determining geographic and grid coordinates and their use are discussed in paragraphs 384 and 385.

401. Approximate Azimuth Mark

The methods of obtaining the approximate azimuth to the azimuth mark are discussed in paragraph 386.

402. Records of Field Data

The method of recording field data for astronomic observations (hour-angle method) is discussed in paragraph 206.

403. Techniques

The techniques for the hour-angle method are the same as for the altitude method (par. 387) except the vertical angle is not measured.

Section III. COMPUTATIONS

404. Computation of Azimuth by the Hour-Angle Method

Because of the difference in solar time and sidereal time, a different form must be used when the azimuth is computed using a star than when it is computed using the sun. The form used for the hour-angle method, sun, is DA Form 6-10. This form is discussed in paragraph 405. The form used for hour-angle method, star, is DA Form 6-10a. This form is discussed in paragraph 406.

405. Use of DA Form 6-10

a. Determination of azimuth by the hour-angle method depends on solution of the astro-

nomie (PZS) triangle when two sides and the included angle are known. The two sides required are polar distance (par. 363a) and colatitude (par. 363c). The included angle is the local hour angle (pars. 364c and 365). DA Form 6-10 provides a convenient step-by-step means for computing the azimuth angle (par. 364b) required, when the sun is the celestial body observed. The horizontal angle measured from the azimuth mark to the sun is applied to the computed azimuth during the last steps, to determine true azimuth to the mark. The formula on which the form is based and a guide for the use of the form are shown on the reverse side.

b. Entries made on DA Form 6-10 are

shown in figures 153 and 154. The data given below are taken from the field notes—

- (1) *Station.* Duncce.
- (2) *Azimuth mark.* Water tower.
- (3) *Latitude.* $34^{\circ} 39' 48''$ N.
- (4) *Longitude.* $98^{\circ} 24' 18''$ W.
- (5) *Area.* Gunnery Hill.
- (6) *Approximate azimuth to azimuth mark.* 4,300 mils.
- (7) *Local date.* 12 March 1961.
- (8) *Watch correction.* 1 second fast ($- 01^s$).
- (9) *Mean time of observation.* $08^h 49^m 48^s$ (S).
- (10) *Mean horizontal angle.* 4,085.5 mils.

c. Spaces are provided on the reverse side of DA Form 6-10 for the auxiliary computations required.

- (1) Declination of the sun at Greenwich mean time of observation is computed as explained in paragraph 391c(2) for entry on line 18 of the form.
- (2) Conversion of latitude and longitude to mils is performed on the reverse side, when required.
- (3) A space is provided for conversion of time to arc, for entry on line 12 of the form.

406. Use of DA Form 6-10a

a. DA Form 6-10a is used to compute azimuth by the hour-angle method when a star is the celestial body observed. The form is used to solve the astronomic (PZS) triangle in the same manner as DA Form 6-10. The steps performed are the same except that the local

hour-angle is determined from sidereal time and right ascension instead of from apparent time. Declination of a star is obtained from the Army Ephemeris for Greenwich date of observation, eliminating the auxiliary computation required when the sun is observed.

b. Entries made on the form are shown in figures 155 and 156. The data given below are taken from the field notes. The example is from a fourth-order observation.

- (1) *Latitude.* $34^{\circ} 39' 48''$ N.
- (2) *Longitude.* $98^{\circ} 24' 18''$ W.
- (3) *Approximate azimuth to mark.* 240° .
- (4) *Local date.* 11 March 1961.
- (5) *Azimuth mark.* Water tower.
- (6) *Station.* TS-7.
- (7) *Star.* Polaris.
- (8) *Mean time of observation.* $19^h 58^m 36^s$ (S).
- (9) *Watch correction.* 25 seconds slow ($+ 25^s$).
- (10) *Mean horizontal angle.* $114^{\circ} 34' 20''$.
- (11) *Area.* Gunnery Hill.

c. Spaces are provided on the reverse side of the form for certain auxiliary computations required.

- (1) Conversion of latitude and longitude to mils, when required.
- (2) Conversion of time to arc, for entry on line 12 of the form.

407. Grid Azimuth

DA Form 6-20 determines the convergence to be applied to the astronomic azimuth computed on DA Forms 6-10 and 6-10a.

[illegible]

Figure 153. Entries made on front of DA Form 6-10 for computing true azimuth from observations on the sun, hour-angle method.

CONVERSION COMPUTATION (TABLE 5)										
HOURS, MINUTES AND SECONDS (TIME) TO DEGREES, MINUTES AND SECONDS OR MILS (ARC)										
		SET NO. 1			SET NO. 2			SET NO. 3		
		H	M	S	H	M	S	H	M	S
1	(11) OF COMPUTATION	11	21	02						
2	DEGREES OR MILS IN HOURS OF (1)	165	00	00						
3	DEGREES AND MINUTES OR MILS IN MINUTES OF (1)	5	15	00						
4	MINUTES AND SECONDS OR MILS IN SECONDS OF (1)		00	30						
5	(2)+(3)+(4) [ENTER IN (12) ON FRONT]	170	15	30						

CONVERSION TO MILS COMPUTATION (USE TABLE III b OF TM 6-230)									
LONGITUDE (FROM FRONT OF FORM)					LATITUDE (FROM FRONT OF FORM)				
	D	M	S	"		D	M	S	"
1	# IN HUNDREDS OF DEGREES OF (1)				10	# IN TENS OF DEGREES OF (10)			
2	# IN TENS OF DEGREES OF (1)				11	# IN UNITS OF DEGREES OF (10)			
3	# IN UNITS OF DEGREES OF (1)				12	# IN TENS OF MINUTES OF (10)			
4	# IN TENS OF MINUTES OF (1)				13	# IN UNITS OF MINUTES OF (10)			
5	# IN TENS OF SECONDS OF (1)				14	# IN TENS OF SECONDS OF (10)			
6	# IN UNITS OF SECONDS OF (1)				15	# IN TENS OF SECONDS OF (10)			
7	# IN UNITS OF SECONDS OF (1)				16	# IN UNITS OF SECONDS OF (10)			
8	SUM OF (2) THROUGH (7)				17	SUM OF (11) THROUGH (16)			
9	SUM OF (2) THROUGH (7) [ENTER IN (12) ON FRONT AND ON DA FORM 6-20]					[ENTER IN (17) ON FRONT AND ON DA FORM 6-20]			

GIVEN:

Time zone of area of operation.

FIELD DATA:

Latitude and longitude of station.

Approximate azimuth to azimuth mark.

Name(s) and number(s) of selected star(s).

Local date of observation.

Mean watch time of observation and watch correction to nearest second.

Horizontal clockwise angle from azimuth mark to star.

GUIDE:

Enter observed field data in block marked.

When using a mil-graduated instrument, --

- (2) through (5) of CONVERSION COMPUTATION are computed using hundredth-mil values.
 - (2) through (9) and (11) through (17) of CONVERSION TO MILS COMPUTATION are computed using hundredth-mil values.
 - (12) through (24) of computation are computed using hundredth-mil values.
 - (25) through (41) of computation are computed using tenth-mil values.
- Value in (41) should be about equal to approximate azimuth to azimuth mark. Continue computations using DA Form 6-20 to obtain the UTM grid azimuth.

LIMITATIONS:

This form should not be used when accuracies greater than fourth-order are required. The hour-angle method should not be used when the star is more than 60 degrees above horizon.

RESULTS:

A value of astronomical azimuth for each set of observations.

FORMULAS:

$$\tan \frac{1}{2} (A + q) = \frac{\cos \frac{1}{2} (Lat - Dec)}{\sin \frac{1}{2} (Lat + Dec)} \cot \frac{1}{2} t$$

$$\tan \frac{1}{2} (A - q) = \frac{\sin \frac{1}{2} (Lat - Dec)}{\cos \frac{1}{2} (Lat + Dec)} \cot \frac{1}{2} t$$

A = astronomical azimuth of star measured east or west of meridian.

q = parallactic angle (cancels in computations).

Lat = latitude of station.

Dec = declination of star.

t = hour angle (less than 12^h) of star.

Figure 154. Auxiliary computations and instructions on back of DA Form 6-10.

COMPUTATION - ASTRONOMIC AZIMUTH BY HOUR - ANGLE METHOD, STAR										TABLE NRS REFER TO TM 6-300 - 1961		STAR NAME AND NR (TABLE 9) POLARIS	
LATITUDE OF STATION		LONGITUDE OF STATION		APRX AZ TO AZ ME		LOCAL DATE		AZIMUTH MARK		STATION			
34° 39' 48" N		98° 24' 18" W		240°		11 MAR 61		WT		TS 7			
1 MEAN WATCH TIME OF OBSERVATION		SET HR 19 58 36		SET HR		SET HR		21 REPEAT (17)		SET HR 34 39 48			
2 WATCH CORRECTION SLOW +		25		+		+		22 REPEAT (18) WITH OPPOSITE SIGN		89 05 07			
3 ALGEBRAIC SUM (1) AND (2)		19 59 01		+		+		23 ALGEBRAIC SUM (21) AND (22)		54 25 19			
4 TIME ZONE CORRECTION LONG +		6		+		+		24 1/2 DP (23)		27 12 40			
5 ALGEBRAIC SUM (3) AND (4)		25 59 01		+		+		25 LOG COS (24)		9.949 0618			
6 GREENWICH DATE * 12 MAR 61		24 00 00		24 00 00		24 00 00		26 LOG COT (18)		0.139 9084			
7 GREENWICH MEAN TIME (GMT) *		01 59 01						27 (25) + (26)		0.088 9702			
8 SIDEREAL TIME AT 0° ON GREENWICH DATE (TABLE 3)		11 17 36						28 LOG SIN (20)		9.945 4276			
9 CORRECTION TO (7) (TABLE 4)		0 20						29 (27) - (28)		0.143 5426			
(3) + (7) + (8)		13 16 57						30 ANGLE HAVING LOG TAN (29)		54 18 03			
(IF LESS THAN (18), ADD 36 HRS)		24 00 00		24 00 00		24 00 00		31 LOG SIN (34)		9.660 1731			
10 RIGHT ASCENSION OF STAR (TABLE 10, 10-HRS, OR 11)		13 16 57						32 REPEAT (25)		0.139 9084			
11 (9) - (10)		11 21 02						33 (21) + (32)		9.800 0815			
12 [(1) CONVERTED TO ARC (5) OF CONV COMP ON REVERSE]		170 15 30						34 LOG COS (20)		9.673 3945			
13 LONGITUDE (6) OF CONVERSION TO MILS EAST + WEST -		98 24 18		+		+		35 (33) - (34)		0.126 6870			
14 ALGEBRAIC SUM (12) AND (13)		71 51 12		+		+		36 ANGLE HAVING LOG TAN (35)		53 14 27			
(14) IS: (15) IS: REPEAT (14)		71 51 12		+		+		37 REPEAT (30)		54 18 03			
0° TO +180° 360° - (14), SIGN (-)		35 55 36		+		+		IF (20) AND (34) HAVE SAME SIGNS, USE (34) + (27)		53 14 27			
MORE THAN 360° (14) - 360°, SIGN (+)		34 39 48		+		+		IF (20) AND (34) HAVE OPPOSITE SIGNS, SUBTRACT SMALLER (34) OR (37), FROM LARGER, (37) OR (34)		1 03 36			
16 1/2 DP (15)		35 55 36		+		+		WHEN STATION IS IN: (20) IS: (30) IS: REPEAT (20)		359 59 60			
17 LATITUDE (17) OF CONVERSION TO MILS NORTH + SOUTH -		34 39 48		+		+		NORTH LATITUDE: (15) IS: (20) IS: REPEAT (20)		1 03 36			
18 DECLINATION OF STAR ON GREENWICH DATE (TABLE 10, 10-HRS, OR 11)		89 05 07		+		+		SOUTH LATITUDE: (15) IS: (20) IS: REPEAT (20)		358 56 24			
19 ALGEBRAIC SUM (17) AND (18)		23 44 55		+		+		40 MEAN HORIZONTAL ANGLE		114 34 20			
20 1/2 DP (19)		61 52 28		+		+		41 (39) - (40) = ASTRONOMIC AZIMUTH TO MARE		244 22 04			
* IF (5) IS: (14) AND LESS THAN 36 HRS (14) AND MORE THAN 36 HRS (14) - 360°, SIGN (-)		GREENWICH DATE (5) IS: LOCAL DATE LOCAL DATE + 1 DAY LOCAL DATE - 1 DAY		AND GMT (5) IS: SAME AS (5) (5) - 36 HRS 36 HRS - (5)		COMPUTER SMITH		CHECKER JONES		SHEET 1 OF 1 SHEETS			

DA FORM 6-10a

REPLACES EDITION OF 1 SEP 53, WHICH IS OBSOLETE.

Figure 155. Entries made on front of DA Form 6-10a for computing true azimuth from fourth order observation on the star Polaris, hour-angle method.

CONVERSION COMPUTATION (TABLE 5)									
HOURS, MINUTES AND SECONDS (TIME) TO DEGREES, MINUTES AND SECONDS OR MILS (ARC)									
1	1111 OF COMPUTATION	2	39 57	3		4		5	
2	DEGREES OR MILS IN HOURS OF (1)	5	33 33	3		4		5	
3	DEGREES AND MINUTES OR MILS IN MINUTES OF (1)	1	73 33	3		4		5	
4	MINUTES AND SECONDS OR MILS IN SECONDS OF (1)		4 22	3		4		5	
5	(12) (13) (14)	7	10 888	3		4		5	
CONVERSION TO MILS COMPUTATION (USE TABLE III b OF TM 6-230)									
1	LONGITUDE (FROM FRONT OF FORM)	98	24	18	10	LATITUDE (FROM FRONT OF FORM)	34	39	48
2	# IN HUNDREDS OF DEGREES OF (1)				11	# IN TENS OF DEGREES OF (10)	5	33	33
3	# IN TENS OF DEGREES OF (1)	16	00	00	12	# IN UNITS OF DEGREES OF (10)		71	11
4	# IN UNITS OF DEGREES OF (1)	1	42	22	13	# IN TENS OF MINUTES OF (10)		8	89
5	# IN TENS OF MINUTES OF (1)		5	93	14	# IN UNITS OF MINUTES OF (10)		2	67
6	# IN UNITS OF MINUTES OF (1)		1	19	15	# IN TENS OF SECONDS OF (10)		0	20
7	# IN TENS OF SECONDS OF (1)		0	05	16	# IN UNITS OF SECONDS OF (10)		0	04
8	# IN UNITS OF SECONDS OF (1)		0	04	17	SUM OF (11) THROUGH (16)	6	16	24
9	SUM OF (1) THROUGH (17) (ENTER IN (13) ON FRONT AND ON DA FORM E - 30)	17	49	43	17	[ENTER IN (17) ON FRONT] (AND ON DA - FORM E - 30)			

AUXILIARY COMPUTATION FOR APPARENT DECLINATION OF SUN AT GREENWICH DATE AND GMT										
1	GREENWICH DATE (A) OF COMPUTATION	12	March	61	2	GMT (HOURS AND MINUTES IN (A) OF COMPUTATION)	14	50		
3	NUMBERS OF HOURS IN (2) X 60	840			4	NUMBER OF MINUTES IN (2)	50			
5	(12) (14)	890			6	DAILY CHANGE IN DECLINATION (TABLE 7)	6	99		
7	LOG OF (5)	2	949	390	8	LOG OF (6)	0	844	477	
9	LOG OF CONSTANT	6	841	638	6	841	6375	6	841	6375
10	(7) + (8) + (9)	0	635	505	11	NUMBER HAVING LOG (10) SECONDS OR MILS OF CHANGE	4	32		
12	APPARENT DECLINATION AT P ON GREENWICH DATE (TABLE 2)	5	62	16	13	(11) CONVERTED TO MINUTES AND SECONDS OR (12) IN MILS (USE SIGN OF (A))	4	32		
14	ALGEBRAIC SUM (12) AND (13) ENTER IN (18) ON FRONT	5	57	84	14					

GIVEN:

Time zone of area of operation.

FIELD DATA:

Latitude and longitude of station.

Approximate azimuth to azimuth mark.

Local date of observation.

Mean watch time of observation and watch correction to nearest second.

Horizontal clockwise angle from azimuth mark to sun.

GUIDE:

Enter observed field data in block marked.

When using a mil-graduated instrument, --

- (2) through (5) of CONVERSION COMPUTATION are computed using hundredth-mil values.
- (2) through (9) and (11) through (17) of CONVERSION TO MILS COMPUTATION are computed using hundredth-mil values.
- (12) through (24) of computation are computed using hundredth-mil values.
- (6) through (14) of AUXILIARY COMPUTATION are computed using hundredth-mil values.
- (25) through (41) of computation are computed using tenth-mil values.

Value in (41) should be about equal to approximate azimuth to azimuth mark. Continue computations using DA Form 6-20 to obtain the UTM grid azimuth.

LIMITATIONS:

This form is not to be used when accuracies greater than fourth-order are required. The hour-angle method should not be used when the sun is more than 60 degrees above horizon.

RESULTS:

A value of astronomic azimuth for each set of observations.

FORMULAS:

$$\tan 1/2 (A + q) = \frac{\cos 1/2 (Lat - Dec)}{\sin 1/2 (Lat + Dec)} \cot 1/2 t$$

$$\tan 1/2 (A - q) = \frac{\sin 1/2 (Lat - Dec)}{\cos 1/2 (Lat + Dec)} \cot 1/2 t$$

A = astronomic azimuth of sun measured east or west of meridian.

q = parallactic angle (cancels in computations).

Lat = latitude of station.

Dec = apparent declination of sun.

t = hour angle (less than 12^h) of sun.

Figure 156. Auxiliary computations and instructions on back of DA Form 6-10a.

CHAPTER 24

AZIMUTH BY SIMULTANEOUS OBSERVATIONS

408. General

Because of the great distances of celestial bodies from the earth, the directions to a celestial body at any instant from two or more close points on the earth are approximately equal. The difference between the azimuths is primarily due to the fact that the azimuths at different points are measured with respect to different horizontal planes. This difference can be determined. The principles in paragraph 409 provide a simple and rapid means of transmitting direction between points by simultaneous observations.

409. Transmission of Direction by Simultaneous Observations on Celestial Bodies

a. A master station is established at a point which can be identified on a large-scale map and from which the grid azimuth to an azimuth mark is known or has been determined. Flank stations are established at points which can be identified on a large-scale map and at which it is desired to determine common grid azimuths. Wire or radio communication must be available between each flank station and the master station. An observing instrument is set up at the master station and oriented on the azimuth mark. An observing instrument is set up at each flank station and oriented on an azimuth mark to which the azimuth is desired. (Direction can be transmitted to more than one flank station at the same time.) A prominent celestial body at an altitude between 10° and 65° is selected by the observer at the master station and identified to the observer at each flank station. (The observer at the master station must wear a lip or throat microphone so that he can transmit information at

the same time that he is observing a celestial body. A loudspeaker, headset, or other device must be provided at each flank station so that the observer can hear instructions from the observer at the master station while he is pointing.) The master station reports its coordinates (encoded if necessary) to each flank station and each flank station notifies the master station when ready to observe. When all stations are ready, the observer at the master station announces, "*Ready—begin tracking—3—2—1—tip.*" Pointings are made on the celestial body as explained in paragraphs 379 and 397, depending on which instrument is used. However, each flank station observer, if he is observing the sun, keeps his vertical crosshair (crossline) tangent to the leading edge of the sun and approximately bisects the sun with the horizontal crosshair (crossline). The master station observer announces "*Tip*" the instant the star is at the intersection of the crosshairs or the instant the sun is tangent to both crosshairs. The master station observer records the readings on the horizontal and vertical scales. Each flank observer records the reading on the horizontal scales when observing the sun and the readings on the horizontal and vertical scales when observing a star. (The vertical angle is read at the flank station(s) only as an aid for identification.) All observers then plunge their telescopes and observe the celestial body (with the telescope in the reverse position), using the procedure required for their instrument. If observing the sun, each flank station observer tracks with the vertical crosshair tangent to the trailing edge of the sun. After both pointings, each flank station acknowledges if the observation was successful. He reports "*Take again*" if

they were not successful. After each set of pointings in which one or more flank stations tracked successfully, the horizontal angle at the master station, from the azimuth mark to the celestial body, is determined from the observed data. This horizontal angle is then added to the grid azimuth from the master station to the azimuth mark to obtain the grid azimuth to the observed celestial body. This grid azimuth and the mean vertical angle to the celestial body are transmitted to each flank station.

b. At each flank station, the locations of both stations are plotted on a large-scale map (fig. 157). A line is then drawn on the map representing the azimuth to the celestial body at the master station. The perpendicular distance (D) to this line from the flank station is then measured.

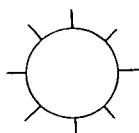
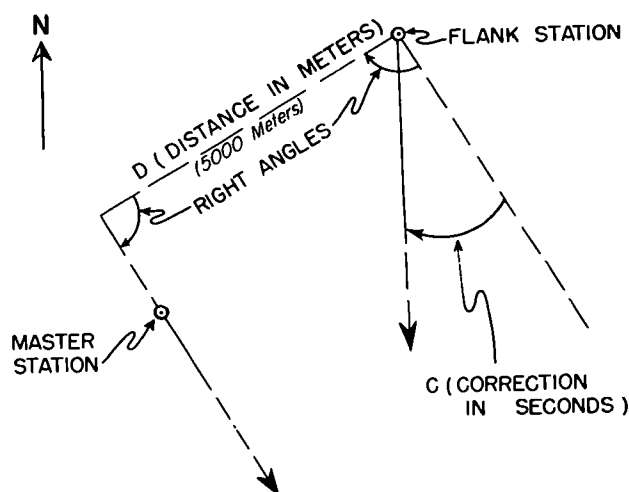


Figure 157. Relative locations of the master station, the flank station, and the celestial body.

c. By using the nomograph shown in figure 158 (also contained in TM 6-300-61, a line is drawn to connect the mean observed altitude

at the master station (H) and the distance (D). This line will intersect the center scale (C) at a point corresponding to the correction in seconds (or mils) to be applied to the azimuth at the master station to determine the correct azimuth from the flank station to the celestial body. When the nomograph is used, it may be necessary to multiply the indicated value in meters by 10, 100, etc. In this case, the indicated correction in seconds (or mils) must also be multiplied by the same number. The correction is applied to the grid azimuth of the celestial body (determined at the master station) in accordance with the following rules:

- (1) When the flank station is to the left of the line from the master station to the celestial body, the correction is added to the azimuth.
- (2) When the flank station is to the right of the line from the master station to the celestial body, the correction is subtracted from the azimuth.

d. The corrected azimuth obtained in c above is the grid azimuth of the celestial body from the flank station. The mean of the observed horizontal angle at the flank station, from the azimuth mark to the celestial body, is then subtracted from this azimuth to obtain the grid azimuth to the azimuth mark. For this subtraction, it may be necessary to add 360° or 6400 mils to the azimuth of the celestial body.

e. If necessary, the master station may use an assumed starting azimuth to the azimuth mark.

410. Example of Transmission of Direction by Simultaneous Observations

The following example illustrates the transmission of direction to one flank station by simultaneous observations:

a. Mean data obtained from observations are as follows:

Master station

Horizontal angle = 2191.0 mils

Vertical angle = 720.0 mils

Flank station

Horizontal angle = 1715.4 mils

b. Given grid azimuth to
azimuth mark at
master station = 1874.5 mils
Mean observed horizontal
angle at
master station = (+) 2191.0 mils
Grid azimuth to celestial
body at master
station = 4065.5 mils

c. The relative locations of the master station, the flank station, and the celestial body are shown in figure 157.

d. The nomograph (fig. 158) is entered by using the mean vertical angle H from *a* above and the distance D, obtained from figure 157. The correction obtained from the nomograph is +0.68 or 0.7 mil. By applying this correction to the grid azimuth from the master station to the celestial body, an azimuth of 4066.2 mils is obtained. This is the grid azimuth from the flank station to the celestial body.

e. Correct grid azimuth
from flank station
to celestial body = 4066.2 mils
Mean observed horizontal
angle at flank
station = (—) 1715.4 mils
Azimuth to azimuth
mark at flank
station = 2350.8 mils

411. Additional Observations

In the event of unsuccessful observations at any flank station, the master station should repeat the procedure. By establishing the number of observations and the rejection limits in a similar manner to those established for astronomic observation, direction can be transmitted through simultaneous observation with accuracy comparable to astronomic observations.

TABLE 13. Grid Azimuth Correction, Simultaneous Observation

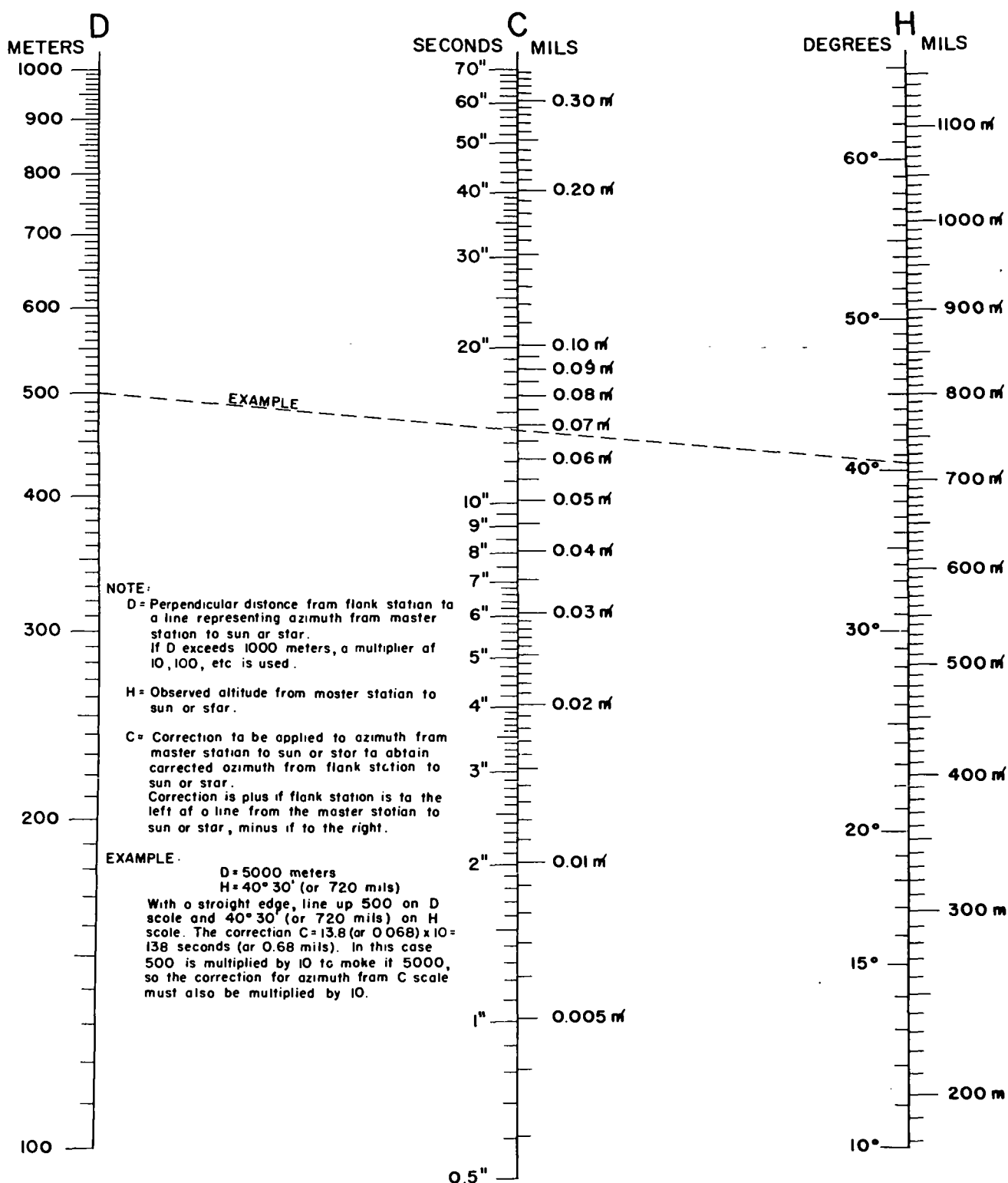


Figure 158. Simultaneous observation, grid azimuth, correction nomograph.

CHAPTER 25

COMPARISON OF METHODS

412. General

The two methods of astronomic observations used by the artillery to determine the azimuth for survey are the altitude and the hour-angle method. An experienced observer using proper observing procedures can compute the required azimuth accurately by either of these methods. An extensive knowledge of astronomy is not required.

413. Astronomic Triangle (PZS)

Both the hour-angle and the altitude methods require the solving of the PZS triangle. The solving of the PZS triangle has been simplified by the use of Department of the Army forms for computations. The elements of the PZS triangle used in each method are shown in figure 159.

414. Fieldwork

The fieldwork required for either the hour-angle or the altitude method is as follows:

Element required	Hour-angle method	Altitude method
Horizontal angle	Yes	Yes
Vertical angle	No	Yes
Time	Yes	Yes
Temperature	No	Yes
Latitude	Yes	Yes
Longitude	Yes	Yes

415. Hour-Angle Method

a. Computing Azimuth by the Hour-Angle Method. The hour-angle method of observation and computation for determining azimuth can be used at any time that the altitude method is used; it is always used for observing Polaris and other celestial bodies which are not in the desired position for the altitude method of observation. The azimuth of the celestial body is computed for the mean time of observation. The horizontal angle from the azimuth mark to the celestial body and the mean time of observation are determined by field observations. In the computations, three elements of the PZS triangle are used—the local hour angle, co-latitude, and polar distance.

- (1) Time is the critical element in an hour-angle observation, since it is

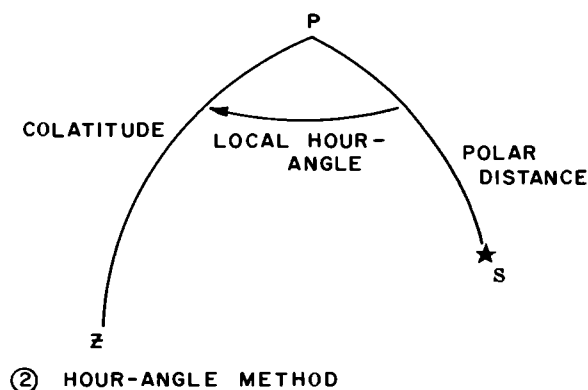
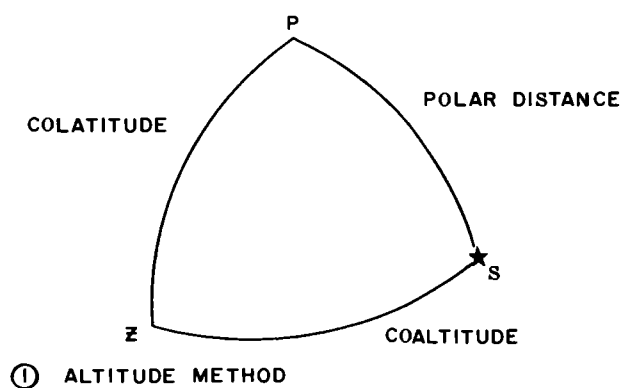


Figure 159. PZS triangle.

used to compute the hour angle. The elements in this determination vary with choice of the celestial body. The following computations are used to determine the hour angle for the sun and stars:

Sun

Change LMT to GMT
 GMT + equation of time = GAT
 GAT $\pm$ 12 hours = GHA
 GHA — west longitude (or + east longitude) = LHA

Star

Change LMT to GMT
 Determine GST by using the Army Ephemeris
 GST — RA = GHA
 GHA — west longitude (or + east longitude) = LHA

- (2) Latitude is used to determine the colatitude.
- (3) The declination (taken from the Army Ephemeris) is used to determine the polar distance.

b. Limitations.

- (1) The hour-angle method can be used when the celestial body is below 20° altitude; however, as the line of sight approaches the observer's horizon, an error (horizontal refraction) which cannot be corrected may be introduced.
- (2) The celestial body should not be observed at a position above 45° in altitude, unless special eyepieces are available for the instrument.
- (3) Time accurate to 1 second is required, except when Polaris is observed (10 seconds).
- (4) The sun should not be observed when it is within 2 hours of the observer's meridian. The accuracy with which the azimuth may be determined depends on the precision of field observations, the accuracy of the corrections in altitude, and the shape of the celestial triangle. The PZS triangle becomes weak as the sun approaches the

observer's meridian, and the solution becomes indeterminate at the instant of apparent noon.

416. Altitude Method

a. Computing Azimuth by the Altitude Method. The altitude method of observation and computation for determining azimuth is the most common method used by the artillery. The azimuth of the celestial body is computed for the mean time of observation. The horizontal angle from the the azimuth mark to the celestial body, the mean vertical angle to the celestial body, the mean time of observation, and the temperature at the time of observation are determined by field observations. In the computations, three elements of the PZS triangle are used—the coaltitude, colatitude, and polar distance.

- (1) The vertical angle is the critical element in an altitude observation. From the vertical angle, the coaltitude is determined. The vertical angle to the sun must be corrected for parallax (the correction is always plus), because the vertical angle is measured from a point on the surface of the earth and not from the center of the earth. No parallax correction is needed for observations on the stars, because they are at such great distances from the earth that the vertical angle is the same as though it were measured from the center of the earth. Although the parallax correction is applied to the vertical angle on the sun only, the refraction correction (always minus) is applied to the vertical angle to any celestial body. When a ray of light emanating from a celestial body passes through the atmosphere of the earth, the ray is bent downward; hence, the sun and stars appear to be higher above the observer's horizon than they actually are. The angle formed by the ray's deviation from its direction on entering the earth's atmosphere to its direction at the surface of the earth is called re-

fraction. The magnitude of the refraction correction depends on the temperature and barometric pressure of the atmosphere and the altitude of the ray. The refraction correction tables give corrections for a barometric pressure of 29.5 inches, which is assumed to be of sufficient accuracy for practical purposes. The parallax correction is determined and applied to the refraction correction, and the final correction is subtracted from the observed altitude.

- (2) The latitude and declination for the determination of the colatitude and polar distance are used the same as in the hour-angle method.

b. Limitations.

- (1) Polaris is never observed by using the altitude method, because it is located near the observer's meridian and presents a poor trigonometric solution.
- (2) Best results with the altitude method can be obtained if observations are made on celestial bodies which are located within 30° of the prime vertical and between 20° and 45° in altitude. In such cases, the celestial body is changing faster in vertical angle than in azimuth, and any error in vertical angle will make a smaller corresponding error in azimuth.
- (3) The body should not be observed when it is within 2 hours of the observer's meridian.

417. Accuracies and Techniques

a. Accuracy. Either the altitude or hour-angle method gives the required accuracy.

b. Determination of Final Azimuth.

- (1) When using the Wild T2 theodolite, observe and compute at least three sets. Mean the three azimuths and reject any azimuth which is more than 30 seconds from the mean. At least two azimuths must remain and be meaned to obtain an azimuth for use with a fourth-order survey.
- (2) The Wild T16 theodolite is used to determine fifth-order astronomic azi-

muths. At least three sets of observations must be observed, and sets varying from the mean by more than 0.3 mil must be rejected. At least two sets must remain and be meaned.

- (3) The M2 aiming circle and the transit can be used for astronomic observation. The procedures for measuring angles outlined in chapters 5 and 6 are applicable to astronomic observation. The number of sets and the rejection limits are as outlined in appendix II.

c. Azimuth Checks and Improvement. Azimuths may be checked and improved by using the following methods:

- (1) A final azimuth, as described in *b* above, determined from observations on the sun before noon, may be checked and improved by determining another final azimuth on the sun in the afternoon. The same observer's position and azimuth mark are used. The two final azimuths are meaned.
- (2) Another method of improving or checking an azimuth is to use an *east* and a *west* star and mean the final azimuths.

418. Summary of Hour-Angle and Altitude Methods

a. For either the hour-angle or altitude method, the best results are obtained when the celestial body is observed within 30° of the prime vertical and between 20° and 45° altitude.

b. When the hour-angle method is used, time accurate to 1 second is required, except when Polaris is observed (10 seconds). It is the best method for observations on circumpolar stars.

c. When the altitude method is used, the celestial body must be observed within 30° of the prime vertical. This is the best method for observations on an east or west star.

d. The sun should not be observed when it is within 2 hours of the observer's meridian.

e. For best results, a celestial body should not be observed when it is less than 20° in altitude.

f. There are days, especially during the winter months at the higher latitudes in the Northern Hemisphere, when the sun or stars do not enter the most desired position for astronomic observations. Under these circumstances, the best results are obtained by observing the celestial body at the highest point in its orbit, yet not within 2 hours before or

after the body has crossed the observer's meridian.

g. If an azimuth is needed and no celestial body is in the proper position for observation, the celestial body that is closest to the proper position will be observed. The hour-angle method is used for best results.

PART SIX

CONVERTING SURVEY CONTROL, CONVERSION OF COORDINATES, AND TRANSFORMATION

CHAPTER 26

CONVERTING SURVEY CONTROL

419. General

a. In order to permit the delivery of accurate field artillery fires without adjustment and to permit the massing of fires from two or more artillery units, all field artillery units operating under the tactical control of one commander should be located and oriented with respect to a single datum or grid. This grid can be based on the UTM (UPS) grid coordinates of points previously established by survey, or the grid may be based on assumed data.

b. The common grid used is the one established by the highest survey echelon present in the area. The headquarters which exercise tactical control over artillery units are battalion, division, and corps. The mission of the subordinate unit requires it to initiate survey operations without waiting for survey control to be established by a higher echelon. Therefore, at all levels, survey is started and completed as soon as possible, and, when higher echelon survey control becomes available, the original data is converted to place the unit on the grid of the higher echelon. Thus, it may be necessary for a battalion assigned or attached to a division artillery to operate first on the grid established by the battalion (battalion grid), then on the grid established by division artillery (division grid), and finally on the grid established by corps artillery (corps grid). When survey at one or more echelons is based on assumed data, it is necessary to convert

data established by the lower echelon to the grid established by the higher echelon.

420. Variations in Starting Control

The methods by which starting control for field artillery survey may be obtained are listed in *a* through *c* below, in order of preference.

a. *Use of Known Coordinates and Heights of Points Located With Respect to a UTM (or UPS) Grid.* The points for which the coordinates and heights are known may be points established by surveys performed by the higher echelon, or they may be points which were located by surveys performed prior to the start of military operations. The locations of points established prior to the commencement of military operations are contained in trig lists prepared and published by the Corps of Engineers.

b. *Use of Assumed Coordinates and Heights and Correct Grid Azimuth.* Correct grid azimuth can be determined, in many cases, through astronomic observation or through the use of a gyro azimuth surveying instrument. Correct grid azimuth should always be used whenever possible. If both higher and lower survey echelons initiate surveys by using correct grid azimuths, any discrepancy which exists between surveys due to assumption of coordinates will be constant for all points located (fig. 160). When it is necessary to assume the coordinates and height of the starting point, they should approximate the correct co-

ordinates and height as closely as possible. The approximate coordinates can be determined from a large-scale map. (Use of starting data determined from a map must always be considered assumed data.)

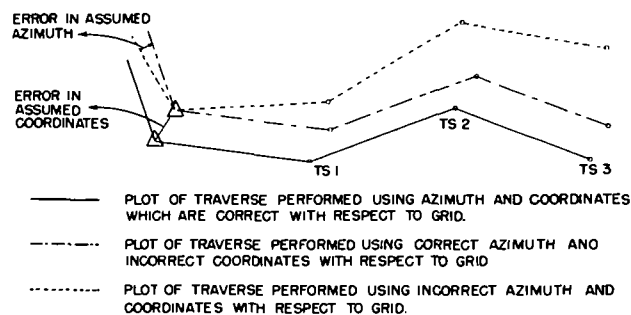


Figure 160. Discrepancies in survey control caused by use of assumed starting data.

c. *Use of Known or Assumed Coordinates and Assumed Azimuth.* Assumed azimuth should be used for a starting azimuth only when azimuth cannot be determined from astronomic observations, a gyro azimuth surveying instrument or computation. The assumed azimuth should closely approximate the correct grid azimuth when possible. The approximate grid azimuth can be determined by scaling from a large-scale map or with a declinated aiming circle. If either (or both) higher or lower echelon survey operations are initiated with assumed azimuths, differences of varying magnitude will exist between the coordinates of points located by their surveys (fig. 160). This variation complicates the

problem of conversion to common control. For this reason, assumed azimuth should never be used when it is possible to use correct grid azimuth.

421. Coordinates and Height Conversion (Sliding the Grid)

When both a higher and a lower survey echelon start survey operations with correct grid azimuth but one (or both) echelon(s) starts (start) with assumed coordinates and height, the lower echelon must apply coordinate and height corrections to the locations of each critical point to convert to the grid of the higher echelon. This coordinate and height conversion is commonly referred to as sliding the grid (fig. 161) and is accomplished as follows:

a. Determine the difference in easting and northing coordinates and the difference in height between the assumed coordinates and height of the starting point and the common grid coordinates and height of the starting point.

	Easting	Northing	Height
Assumed starting point	550000.00	3838000.00	400.0
Common grid starting point	550196.52	3837887.89	402.3
Corrections	+ 196.52	- 112.11	+2.3

b. The difference becomes the correction when the difference is given a sign which will cause the algebraic sum of the assumed data and the correction to equal the common grid data.

c. Apply the corrections algebraically to the coordinates and height (as determined by the lower echelon) of each station to be converted.

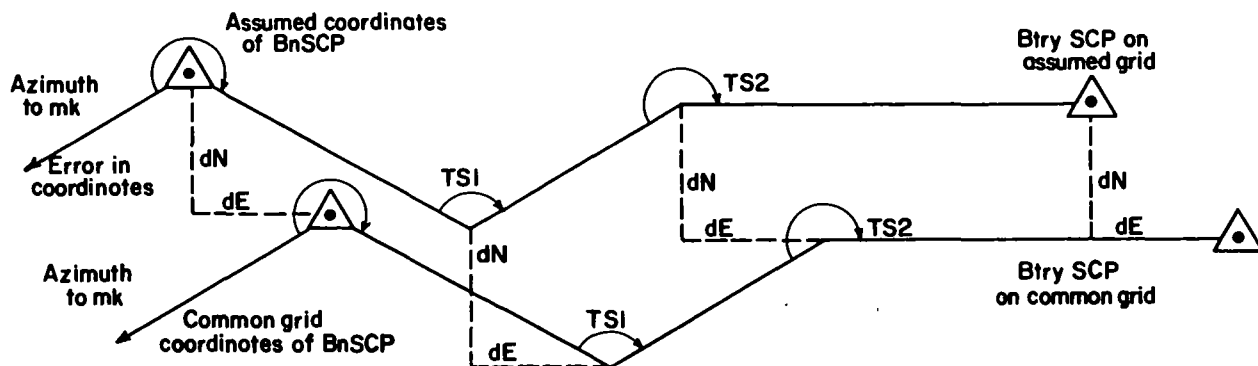


Figure 161. Schematic diagram illustrating sliding the grid.

422. Azimuth Conversion (Swinging the Grid)

If a unit initiates survey operations using correct grid coordinates for the starting point but assumed azimuth, the coordinates of each station in the survey and the azimuths determined by survey will be in error when correct direction is determined for the starting point. In order to convert the assumed data to correct grid data, all azimuths and coordinates determined in the scheme must be corrected. The application of the azimuth correction is commonly referred to as swinging the grid and procedures are as follows:

a. Determine the difference between the assumed starting azimuth and the azimuth given by common control.

Assumed starting azimuth ----- $160^{\circ} 19' 40''$
 Common grid starting azimuth -- $164^{\circ} 24' 20''$
 Azimuth correction ----- $+4^{\circ} 04' 40''$

This difference becomes the azimuth correction when the difference is given a sign which will

cause the algebraic sum of the correction and the assumed azimuth to equal the common grid azimuth.

b. Apply the azimuth correction to each leg of the survey.

c. Since the azimuth of each leg has changed, the bearing angle of each leg has changed. Recompute each leg of the survey by using the corrected azimuths and new coordinates determined for each station in the survey, thus placing all stations on the common grid.

d. If it is desired to determine the common grid data for a specific point only, compute the azimuth and distance from the starting point to the designated point (assumed data). Apply the azimuth correction to the azimuth determined and recompute the location of the designated point from the starting point, using the corrected azimuth and the distance determined by computation (fig. 162).

e. Any orienting lines may be corrected by applying the azimuth correction to the azimuth determined through the use of assumed data.

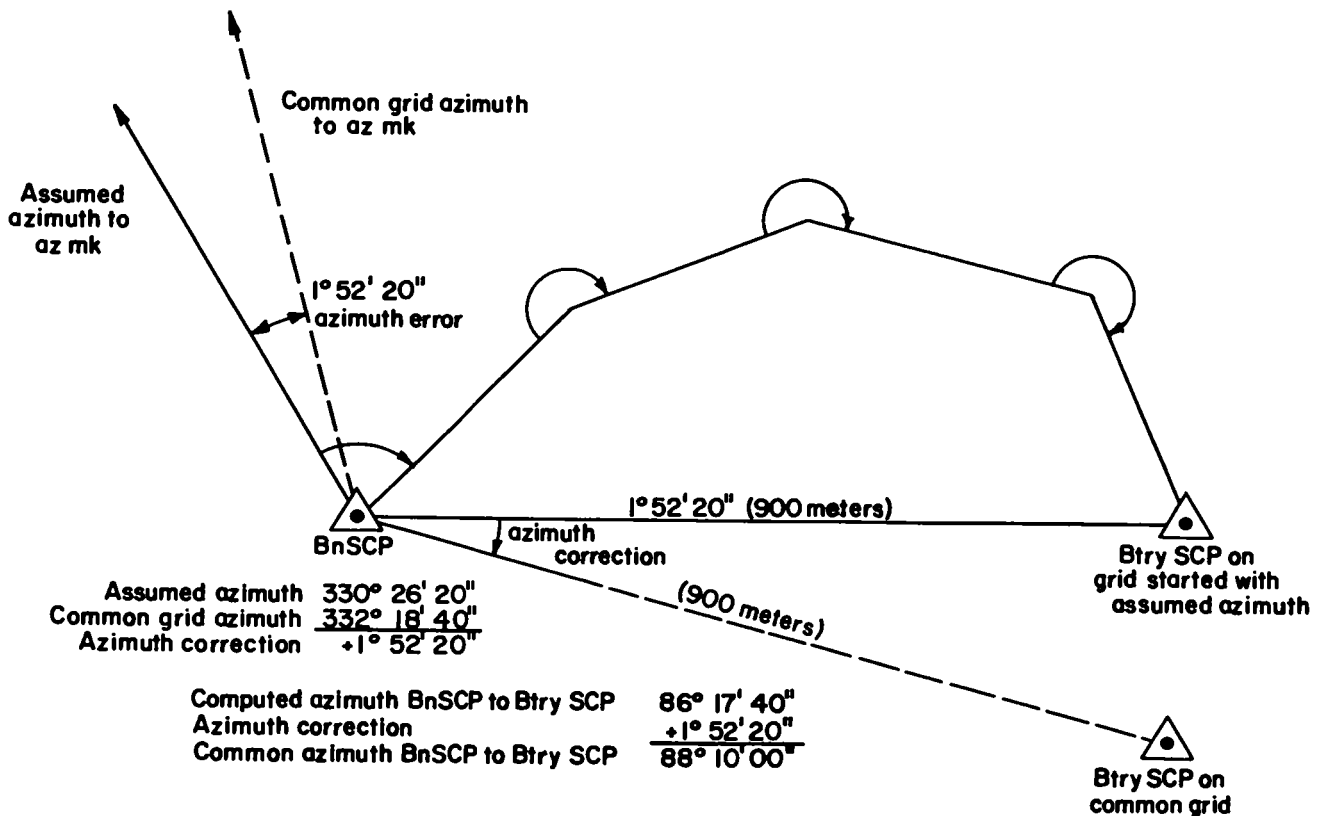


Figure 162. Schematic diagrams illustrating swinging the grid for a specific station.

423. Azimuth, Coordinates, and Height Conversion (Swinging and Sliding the Grid)

If either (or both) a higher or a lower survey echelon initiates survey operations with assumed azimuth, coordinates, and height, the lower echelon must apply azimuth, coordinates and height corrections to critical locations and directions to convert to the grid of the higher echelon. This technique is commonly referred to as swinging and sliding the grid and both

swinging and sliding may be accomplished at the same time. Only the critical points (battery centers, OP's) are converted. The steps in swinging and sliding the grid (fig. 163) are as follows:

- Using the assumed coordinates, compute the azimuth and distance from the starting point to the first critical point, from the first critical point to the second, and so on until the closing point is reached.
- Determine the azimuth correction by com-

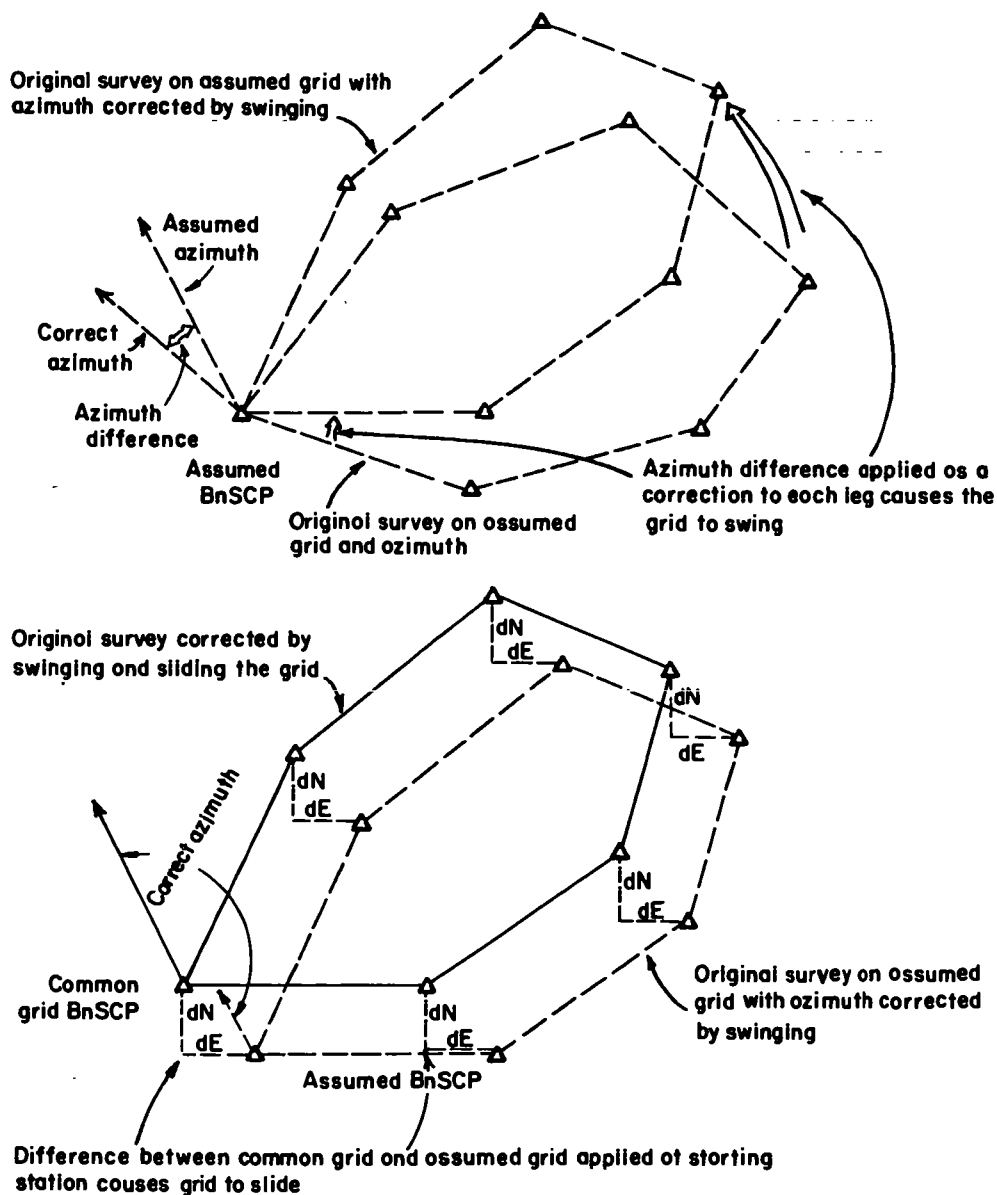


Figure 163. Schematic diagram illustrating swinging and sliding the grid.

paring the assumed starting direction with the common grid starting direction. Apply the azimuth correction to each of the computed azimuths determined in *a* above.

c. Using the common grid coordinates for the starting point, the corrected azimuths (*b* above), and the computed distances between critical points (*a* above), compute the coordinates of the first critical point from the starting point. Using the new coordinates of the first critical point, the corrected azimuth and the computed distance to the second point, recompute the coordinates of the second critical point and so on until the closing point is reached.

d. Correct the height of the critical points by applying the height correction.

424. Swinging and Sliding the Grid (Graphically)

The procedure discussed in paragraph 423 require considerable mathematical computations in order to convert to common control. If time is critical, a graphical solution to conversion to common control can be used. How-

ever, control cannot be extended from any data obtained from a graphical solution. Normally, the graphical solution is used in conjunction with a firing chart. An overlay is made of the existing critical points, including the battalion survey control point and a line of direction to the azimuth mark, and then the critical points are transferred to a new chart. The steps for this procedure are as follows:

a. Plot the coordinate locations, as determined from assumed data, for the battalion SCP and all critical points. Plot the azimuth (assumed) to the mark on the chart.

b. Place a sheet of overlay paper over the chart and prick the locations of the battalion SCP and critical points.

c. Trace the line of direction from the chart to the overlay.

d. Plot the common control coordinates of the battalion SCP and the common control azimuth to the mark on a new chart.

e. Place the overlay on the new chart, aligning battalion SCP on battalion SCP and azimuth line on azimuth line.

f. Prick the locations of all critical points shown on the overlay to the new chart.

CHAPTER 27

CONVERSION OF COORDINATES

425. General

It may occasionally be necessary to convert grid data to geographic data and/or geographic data to grid data. Occasions when this may be necessary or desirable are as follows:

a. When coordinates are transformed from a UTM zone to a UPS zone or from a UPS zone to a UTM zone, it is necessary to convert grid coordinates to geographic coordinates and then to convert the geographic coordinates to grid coordinates for the new zone. (To transform a grid azimuth from a UTM zone to a UPS zone or from a UPS zone to a UTM zone, it is necessary to convert the true azimuth to a grid azimuth for the new zone; this is accomplished by subtracting the convergence from the grid azimuth for the old zone and applying the convergence for the new zone.)

b. When only the geographic coordinates are known for a point which will be used to initiate or check survey operations, it is necessary to convert the geographic coordinates to UTM (or UPS) grid coordinates. (Geographic coordinates must be correct to the nearest 0.001 second to obtain UTM (UPS) coordinates correct to 0.03 meter.)

c. When azimuth is obtained from astronomical observations, it is necessary to know the latitude and longitude of the astronomical observation station. If they are not known, the geographic coordinates of the station can be obtained by conversion from grid coordinates.

426. Conversion of Distance

To determine the distance between two points, the coordinates of both points must be based on a common system (for example, both geographic coordinates or UTM coordinates).

If the distance is computed from UTM coordinates, the log scale factor must be applied to obtain ground distance.

427. Procedures for Conversion of Coordinates

a. The procedures for converting UPS grid coordinates to geographic coordinates and for converting geographic coordinates to UPS grid coordinates are discussed in TM 5-241.

b. In artillery surveys, UTM grid coordinates are converted to geographic coordinates and geographic coordinates are converted to UTM grid coordinates by using DA Form 6-22 (Grid to Geographic (machine)), DA Form 6-23 (Geographic to Grid (logarithm)), and DA Form 6-25 (Geographic to Grid (machine)) together with technical manuals containing data relative to the appropriate spheroid. TM 5-241-1 contains a map showing the various spheroids. A spheroid is an assumed size and shape of the earth for the purpose of computing geodetic positions.

c. The spheroids and their associated technical manuals are shown below—

INTERNATIONAL SPHEROID (SOUTH AMERICA, EUROPE, AUSTRALIA, CHINA, HAWAII, and SOUTH PACIFIC): TM 5-241-3/1 and TM 5-241-3/2.

CLARKE 1866 SPHEROID (UNITED STATES, MEXICO, ALASKA, CANADA, and GREENLAND): TM 5-241-4/1 and TM 5-241-4/2.

BESSEL SPHEROID (JAPAN, USSR, KOREA, BORNEO, CELEBES, and SUMATRA): TM 5-241-5/1 and TM 5-241-5/2.

CLARKE 1880 SPHEROID (AFRICA): TM 5-241-6/1 and TM 5-241-6/2.

EVEREST SPHEROID (INDIA, TIBET, BURMA, MALAY, and THAILAND): TM 5-241-7.

428. Use of DA Form 6-22 (Computation—Conversion UTM Grid Coordinates to Geographic Coordinates (Machine))

DA Form 6-22 (fig. 164) is used to convert UTM grid coordinates to geographic coordinates. Instructions for the use of the form are contained on the reverse side of the form. Figure 164 is an example of the entries that are made on DA Form 6-22 for converting UTM grid coordinates to geographic coordinates. The longitude of the central meridian (item 39) can be obtained from the UTM grid zone number by using the table on the reverse side of DA Form 6-22. The UTM grid zone number can be determined from a map or from a trig list.

429. Use of DA Form 6-23 (Computation—Conversion Geographic Coordinates to UTM Grid Coordinates (Logarithms))

a. DA Form 6-23 (fig. 165) is used to convert geographic coordinates to UTM grid coordinates. Instructions for the use of the form are contained on the reverse side of the form. Figure 165 is an example of the entries that are made on DA Form 6-23 for converting

geographic coordinates to UTM grid coordinates. Longitude of the central meridian (and UTM grid zone number) (item 2) is obtained from the table on the reverse side of DA Form 6-23.

b. Logarithms entered on DA Form 6-23 must be correct to the seventh digit in the mantissa. The complete number, for which the logarithm is obtained, must be used as the argument in obtaining the logarithm. The mantissa of the logarithm must be determined to the eighth digit and then rounded off to the seventh digit. Antilogarithms must be determined to the third digit after the decimal point.

430. Use of DA Form 6-25 (Computation—Conversion Geographic Coordinates to UTM Grid Coordinates (Machine))

DA Form 6-25 (fig. 166) can also be used to convert geographic coordinates to UTM grid coordinates. (DA Form 6-25 is a machine computation form, whereas DA Form 6-23 is a logarithmic computation form.) Instructions for the use of the form are contained on the reverse side of the form. Figure 166 is an example of the entries that are made on DA Form 6-25 for converting geographic coordinates to UTM grid coordinates. Longitude of the central meridian (and UTM grid zone number) (item 2) is obtained from the table on the reverse side of DA Form 6-25.

COMPUTATION - CONVERSION UTM GRID COORDINATES TO GEOGRAPHIC COORDINATES (MACHINE)									
STATION Flat Top # 2			UTM GRID COORDINATES: E 559 858 430 N 3 836 637 310				HEMISPHERE: ☒ NORTH ☐ SOUTH UTM GRID ZONE NUMBER 14		
1	EASTING COORDINATE OF STATION (As accurately as known)	559	858	430	25°	TABULAR VALUE FUNCTION IX OPPOSITE LATITUDE IN (10)	39	291	762
2		5	0	0	0	0	0	0	0
3	IF (1) IS MORE THAN (2), USE (1) - (2) IF (1) IS LESS THAN (2), USE (2) - (1) (Sign always +)	59	858	430	26°	TABULAR DIFFERENCE FOR 1 SECOND OPPOSITE TABULAR VALUE OF FUNCTION IX IN (25)	0	131	19
4	REPEAT (3) WITH DECIMAL POINT MOVED LEFT SIX PLACES	059	858	430	27°	TABULAR VALUE FUNCTION X OPPOSITE LATITUDE IN (10)		315	254
5	(4) X (4)	003	583	032	28°	TABULAR DIFFERENCE FOR 1 SECOND OPPOSITE TABULAR VALUE OF FUNCTION X IN (27)	0	004	23
6	(5) X (4)	000	214	475	29°	GRAPHIC VALUE $\Delta \frac{2}{100}$ USE (27) AS ARGUMENT. ENTER GRAPH AT LEFT SIDE (Sign always -)	(-)		001
7	(6) X (4)	000	012	838	30°	GRAPHIC VALUE E_2 = SECONDS OF ARC USE STEP (4) AS ARGUMENT AT LEFT SIDE OF GRAPH. USE STEP (10) AS ARGUMENT AT TOP OF GRAPH			0
8	NORTHING COORDINATE OF STATION (As accurately as known) IF HEMISPHERE IS SOUTH, USE 10,000,000,000 MINUS NORTHING COORDINATE OF STATION	1	0	0	0	0	0	0	0
9	TABULAR VALUE FUNCTION I NEAREST TO AND LESS THAN VALUE IN (8)	3	835	882	31	(17) X (26)		3	216
10	LATITUDE IN DEGREES AND MINUTES OPPOSITE VALUE IN (9)	34	40		32	ALGEBRAIC SUM (25), (29), AND (31) (Sign always +)	(+)	39	294 977
11	TABULAR DIFFERENCE FOR 1 SECOND OPPOSITE TABULAR VALUE OF FUNCTION I IN (9)	30	801	99	33	(32) X (4) = SECONDS OF ARC (Sign always +)	(+)	2	352 136
12	TABULAR VALUE FUNCTION VII OPPOSITE LATITUDE IN (10)	1	758	849	34	(17) X (28)		0	104
13	TABULAR DIFFERENCE FOR 1 SECOND OPPOSITE TABULAR VALUE OF FUNCTION VII IN (12)	0	018	12	35	(34) + (27)		315	358
14	TABULAR VALUE FUNCTION VIII OPPOSITE LATITUDE IN (10)	23	10		36	(35) X (6) = SECONDS OF ARC (Sign always -)	(-)	0	068
15	GRAPHIC VALUE D_2 = SECONDS OF ARC USE VALUE IN STEP 4 AS ARGUMENT. ENTER GRAPH AT LEFT SIDE (Sign always -)			0	37	ALGEBRAIC SUM (30), (33), AND (36) = SECONDS OF ARC (Sign always +)	(+)	2	352 068
16	(8) - (9)		755	179	38	CONVERT (37) TO DEGREES, MINUTES, SECONDS OF ARC		39	12 068
17	(16) ÷ (11)		24	517	39	LONGITUDE OF CENTRAL MERIDIAN OF UTM GRID ZONE BEING USED (Use table)		99	WEST LONGITUDE
18	(17) + (10) = APPROXIMATE LATITUDE OF STATION IN DEGREES, MINUTES, SECONDS	34	40	24 517	40	LONGITUDE OF STATION IF (39) IS WEST LONGITUDE AND (1) IS LESS THAN (2), USE (38) ÷ (39)		98	59 60 000
19	(13) X (17)		0	444		IF (39) IS WEST LONGITUDE AND (1) IS MORE THAN (2), USE (39) - (38)		39	12 068
20	(19) + (12)	1	759	293		IF (39) IS EAST LONGITUDE AND (1) IS LESS THAN (2), USE (39) - (38)			
21	(20) X (5) = SECONDS OF ARC		6	304		IF (39) IS EAST LONGITUDE AND (1) IS MORE THAN (2), USE (38) + (39)		98	20 47 932
22	CONVERT (21) TO MINUTES AND SECONDS OF ARC (Sign always -)		6	304	* Obtained from UTM Grid Tables for spheroid being used, Volume II.				
23	(7) X (14) = SECONDS OF ARC		0	000	COMPUTER Kissinger				
24	ALGEBRAIC SUM OF (13) AND (22), AND (23) = LATITUDE OF STATION IN HEMISPHERE SHOWN ABOVE	N	34	40 18 213	CHECKER West				
					DATE 19 January 1961				

DA FORM 6-22

Figure 164. Entries made on DA Form 6-22 for converting UTM grid coordinates to geographic coordinates (machine).

COMPUTATION - CONVERSION GEOGRAPHIC COORDINATES TO UTM GRID COORDINATES (Logarithms)									
1	LONGITUDE OF STATION (as accurately as known)	98 23 14 830	STATION	SILL	HEMISPHERE	☒ NORTH ☐ SOUTH			
2	LONGITUDE OF CENTRAL MERIDIAN OF UTM GRID ZONE BEING USED	99 00 00 000	LATITUDE	34 38 31 738	LONGITUDE	98 23 14 830			
3	IF (1) IS MORE THAN (2), USE (1)-(2) IF (1) IS LESS THAN (2), USE (2)-(1) (Sign always +)	0 36 45 170	4	TABULAR VALUE FUNCTION IV OPPOSITE LATITUDE (Degrees, Minutes) OF STATION (+)	254	608 158			
4	CONVERT (3) TO SECONDS OF ARC	2 205 170	45	TABULAR DIFFERENCE FOR 1 SECOND OPPOSITE FUNCTION IV IN (44) (-)	0	848 86			
5	REPEAT (4) WITH DECIMAL POINT MOVED LEFT FOUR PLACES	0, 220 517 0	46	TABULAR VALUE FUNCTION V OPPOSITE LATITUDE (Degrees, Minutes) OF STATION (+)	35	622			
6	LOG (5)	9 343 4421	47	TABULAR DIFFERENCE FOR 1 SECOND OPPOSITE FUNCTION V IN (46) (-)	0	001 03			
7	REPEAT (6)	9 343 4421	48	GRAPHIC VALUE B ₅ [USE LATITUDE (Degrees, Minutes) AS ARGUMENT AT TOP OF GRAPH. USE VALUE IN STEP 13 AS ARGUMENT AT LEFT SIDE OF GRAPH.]	0	0 000			
8	(6) + (7)	8 686 8842	49	GRAPHIC VALUE Δ^2 (14) [USE LATITUDE (Seconds) OF STATION AS ARGUMENT. ENTER GRAPH AT LEFT SIDE.]		003			
9	REPEAT (6)	9 343 4421	50	REPEAT (44)	254	608 158			
10	(8) + (9)	8 030 3263	51	(49) + (50)	254	608 161			
11	REPEAT (6)	9 343 4421	52	LOG (48)	9	928 8361			
12	(10) + (11)	7 373 7684	53	REPEAT (19)	1	501 5796			
13	TABULAR VALUE FUNCTION I OPPOSITE LATITUDE (Degrees, Minutes) OF STATION (+)	3 832 185 907	54	(52) + (53)	1	430 4157			
14	TABULAR DIFFERENCE FOR 1 SECOND OPPOSITE FUNCTION I IN (13) (+)	30 801 82	55	LOG (47)	7	012 8372			
15	TABULAR VALUE FUNCTION II OPPOSITE LATITUDE (Degrees, Minutes) OF STATION (+)	3 507 616	56	REPEAT (19)	1	501 5796			
16	TABULAR DIFFERENCE FOR 1 SECOND OPPOSITE FUNCTION II IN (15) (+)	0 012 92	57	(55) + (56)	8	514 4168			
17	TABULAR VALUE FUNCTION III OPPOSITE LATITUDE (Degrees, Minutes) OF STATION (+)	2 123	58	REPEAT (46)	35	622			
18	GRAPHIC VALUE A ₂ [Use value in Step (3) as argument. Enter Graph at left side.]	0 000	59	NUMBER HAVING LOG (57) [USE SIGN OF (47)]	0	033			
19	LOG (seconds) LATITUDE OF STATION (Use seconds part of latitude of station shown at top of computation)	1 501 5796	60	ALGEBRAIC SUM (58) AND (59)	35	589			
20	LOG (14)	1 488 5761	61	LOG (60)	1	551 3158			
21	(19) + (20)	2 990 1557	62	REPEAT (10)	8	030 3263			
22	REPEAT (19)	1 501 5796	63	(61) + (62)	9	581 6421			
23	LOG (16)	8 111 2625	64	REPEAT (51)	254	608 161			
24	(22) + (23)	9 612 8421	65	NUMBER HAVING LOG (54)	26	941			
25	REPEAT (15)	3 507 616	66	ALGEBRAIC SUM (64) AND (65) (Sign always +)	254	581 220			
26	NUMBER HAVING LOG (24) IF SIGN OF (24) IS (+), USE SIGN (+) IF SIGN OF (24) IS (-), USE SIGN (-)	0 410	67	LOG (66)	5	405 8264			
27	ALGEBRAIC SUM (25) AND (26) (Sign always +)	3 508 026	68	REPEAT (6)	9	343 4421			
28	LOG (27)	3 545 0633	69	(67) + (68)	4	749 2685			
29	REPEAT (8)	8 686 8842	70	NUMBER HAVING LOG (63) [USE SIGN OF (63)]	0	382			
30	(28) + (29)	2 231 9475	71	REPEAT (48)	0	000			
31	LOG (17)	0 326 9500	72	ALGEBRAIC SUM (70) AND (71)	0	382			
32	REPEAT (12)	7 373 7684	73	NUMBER HAVING LOG (59) (Sign always +)	56	139 494			
33	(31) + (32)	7 700 7184	74	REPEAT (72)	0	382			
34	NUMBER HAVING LOG (33) IF SIGN OF (33) IS (+), USE SIGN (+) IF SIGN OF (33) IS (-), USE SIGN (-)	0 005	75	ALGEBRAIC SUM (73) AND (74) (Sign always +)	56	139 876			
35	REPEAT (18)	0 000	76	EASTING UTM GRID COORDINATE OF STATION IF LONGITUDE IS EAST AND (1) IS MORE THAN (2), USE 500,000.000 + (75) IF LONGITUDE IS EAST AND (1) IS LESS THAN (2), USE 500,000.000 - (75) IF LONGITUDE IS WEST AND (1) IS MORE THAN (2), USE 500,000.000 + (75) IF LONGITUDE IS WEST AND (1) IS LESS THAN (2), USE 500,000.000 - (75)	500	000 000			
36	ALGEBRAIC SUM (34) AND (35)	0 005							
37	REPEAT (13)	3 832 185 907							
38	NUMBER HAVING LOG (21) (Sign always +)	977 588							
39	NUMBER HAVING LOG (30) (Sign always +)	170 588							
40	(37) + (38) + (39)	3 833 334 083							
41	REPEAT (34)	0 005							
42	ALGEBRAIC SUM (40) AND (41) (Sign always +)	3 833 334 088							
43	NORTHING UTM GRID COORDINATE OF STATION IF HEMISPHERE OF STATION IS NORTH, REPEAT (42) IF HEMISPHERE OF STATION IS SOUTH, USE 5,000,000.000 - (42)	3 833 334 09							
			*Obtained from UTM Grid Tables for spheroid being used, Volume 1						
			COMPUTER						
			SFC J DOE						
			CHECKER						
			Cpl R ROE						
			DATE						
			1 Feb 61						

DA FORM 6-23
1 SEP 52

Figure 165. Entries made on DA Form 6-23 for converting geographic coordinates to UTM grid coordinates (logarithms).

COMPUTATION - CONVERSION GEOGRAPHIC COORDINATES TO UTM GRID COORDINATES (MACHINE)									
STATION		LATITUDE		LONGITUDE		EAST ☐ WEST ☒		HEMISPHERE ☒ NORTH ☐ SOUTH	
SILL		34 38 31.738		98 23 14.830					
1	LONGITUDE OF STATION (As accurately as known)	98 23 14.830		22*	TABULAR VALUE FUNCTION IV OPPOSITE LATITUDE (Degree, minutes) OF STATION	254		608 158	
2	LONGITUDE OF CENTRAL MERIDIAN OF UTM GRID ZONE BEING USED	99		23*	TABULAR DIFFERENCE FOR 1 SECOND OPPOSITE FUNCTION IV IN (22)	0		848 86	
3	IF (1) IS MORE THAN (2), USE (1)-(2) IF (1) IS LESS THAN (2), USE (2)-(1) (Sign always +)	98 23 14.830		24*	TABULAR VALUE FUNCTION V OPPOSITE LATITUDE (Degree, minutes) OF STATION	35		622	
	(+)	0 136 145 170		25*	TABULAR DIFFERENCE FOR 1 SECOND OPPOSITE FUNCTION V IN (24)	0		001 03	
4	CONVERT (3) TO SECONDS OF ARC	22 05 170		26*	GRAPHIC VALUE B_S [USE LATITUDE (Degree, minutes) AS ARGUMENT AT TOP OF GRAPH. USE VALUE IN STEP (3) AS ARGUMENT AT LEFT SIDE OF GRAPH]	0		000	
5	REPEAT (4) WITH DECIMAL POINT MOVED LEFT FOUR PLACES	0 220 517 0		27*	GRAPHIC VALUE Δ^2 (19) [USE LATITUDE (Seconds) OF STATION AS ARGUMENT. ENTER GRAPH AT LEFT SIDE]	003			
6	(3) X (3)	0 048 627 7		28	(23) X LATITUDE (Seconds) OF STATION	26		941	
7	(4) X (3)	0 010 723		29	(25) X LATITUDE (Seconds) OF STATION	0		033	
8	(7) X (3)	0 002 4		30	ALGEBRAIC SUM (24) AND (29)	35		582	
9*	TABULAR VALUE FUNCTION I OPPOSITE LATITUDE (Degree, minutes) OF STATION	3 832 185 907		31	(30) X (7)	0		382	
10*	TABULAR DIFFERENCE FOR 1 SECOND OPPOSITE FUNCTION I IN (9)	30 801 82		32	ALGEBRAIC SUM (23), (27), AND (28) (Sign always +)	254		581 220	
11*	TABULAR VALUE FUNCTION II OPPOSITE LATITUDE (Degree, minutes) OF STATION	3 507 616		33	(32) X (4) (Sign always +)	56		139 487	
12*	TABULAR DIFFERENCE FOR 1 SECOND OPPOSITE FUNCTION II IN (11)	0 012 102		34	ALGEBRAIC SUM (24), (31), AND (33) (Sign always +)	56		139 869	
13*	TABULAR VALUE FUNCTION III OPPOSITE LATITUDE (Degree, minutes) OF STATION	2 123		35	EASTING UTM GRID COORDINATE OF STATION IF LONGITUDE IS EAST AND (1) IS MORE THAN (2), USE 500,000,000 + (34) IF LONGITUDE IS EAST AND (1) IS LESS THAN (2), USE 500,000,000 - (34) IF LONGITUDE IS WEST AND (1) IS MORE THAN (2), USE 500,000,000 - (34) IF LONGITUDE IS WEST AND (1) IS LESS THAN (2), USE 500,000,000 + (34)	556		139 87	
14*	GRAPHIC VALUE A_S [USE VALUE IN STEP (3) AS ARGUMENT. ENTER GRAPH AT LEFT SIDE]	0 000							
15	(10) X LATITUDE (Seconds) OF STATION	977 588							
16	(12) X LATITUDE (Seconds) OF STATION	0 410							
17	ALGEBRAIC SUM (11) AND (14) (Sign always +)	3 508 026							
18	(17) X (4)	170 587							
19	(13) X (4)	0 005		*OBTAINED FROM UTM GRID TABLES FOR SPHEROID BEING USED, VOLUME I					
20	ALGEBRAIC SUM (9), (14), (18), (19), AND (19) (Sign always +)	3 833 334 087		COMPUTER: SFC J DOE					
21	NORTHING UTM GRID COORDINATE OF STATION IF HEMISPHERE OF STATION IS NORTH, REPEAT (20) IF HEMISPHERE OF STATION IS SOUTH, USE 10,000,000,000 - (20)	3 833 334 09		CHECKER: Cpl R ROE					
				DATE: 1 February 1961					

DA FORM 6-25
1 SEP 52

Figure 166. Entries made on DA Form 6-25 for converting geographic coordinates to UTM grid coordinates (machine).

CHAPTER 28

TRANSFORMATION

431. General

When field artillery units are operating across grid zone junctions, it will frequently be necessary to transform the grid coordinates of points and the grid azimuths of lines from the grid for one zone to the grid for the adjacent zone. Special tables are available through Army Map Service which permit transformation across several zones in a single computation.

a. The method of transforming grid coordinates from a UTM zone to a UPS zone or from a UPS zone to a UTM zone is discussed in paragraph 426.

b. In the UTM grid system there are overlap areas east and west of zone junctions. However, transformation is not restricted to these overlap areas. Grid coordinates (and azimuths) can be transformed from any point in one zone into terms of an adjacent zone. To understand what transpires when transformation is performed, refer to figure 167. Figure 167 shows two adjacent UTM zones, 14 and 15. In terms of northing coordinates they are numbered the same, since the origin of the northing coordinate is the Equator. However, the easting coordinates from left to right are not a continuous series of numbers, since the origin of the easting coordinate for each zone is the central meridian for that zone and is numbered 500,000. Within each zone, the coordinates will increase to the east and decrease to the west from the central meridian. Visualize point P in zone 14. The coordinates are (800,000-3,700,000). If the coordinates of point P were to be transformed to the adjacent grid (zone 15), the action taken would be the equivalent of superimposing the grid of zone 15 over the grid of zone 14 as indicated. Actually, trans-

formation of coordinates involves only the mathematical continuation of the adjacent grid to the grid being used and the subsequent corrections for locations due to the change in grid north reference. Although the location of point P on the ground will not be changed, the value of its original coordinates will change with the transformation. The value in terms of zone 15 would be less than 100,000 meters in easting and greater than 3,700,000 meters in northing. It is apparent that in transformation there will be a major change in the easting coordinates due to the coordinate numbering system of each zone and the change in grid north reference, but there will be only a small change in northing coordinate, based only on the difference in the grid north reference.

432. Use of TM 5-241-2 (Formerly AMS TM No. 50)

a. In using TM 5-241-2 to extract the function required for the formulas used in transformation, determine first the spheroid to be used. This can be accomplished by referring to the map of the world in the back of the technical manual, and using it as an index to determine which spheroid tables should be used. The formulas being solved in transformation computations are also contained in the technical manual.

b. The tables in TM 5-241-2 are compiled for 100,000-meter intervals of easting and northing. A station is considered to be in a 100,000-meter square, and the coordinates of the nearest corner of this square are used for the determination of e' and n' and for the entering arguments.

c. Certain procedures must be followed to insure proper extraction from the tables.

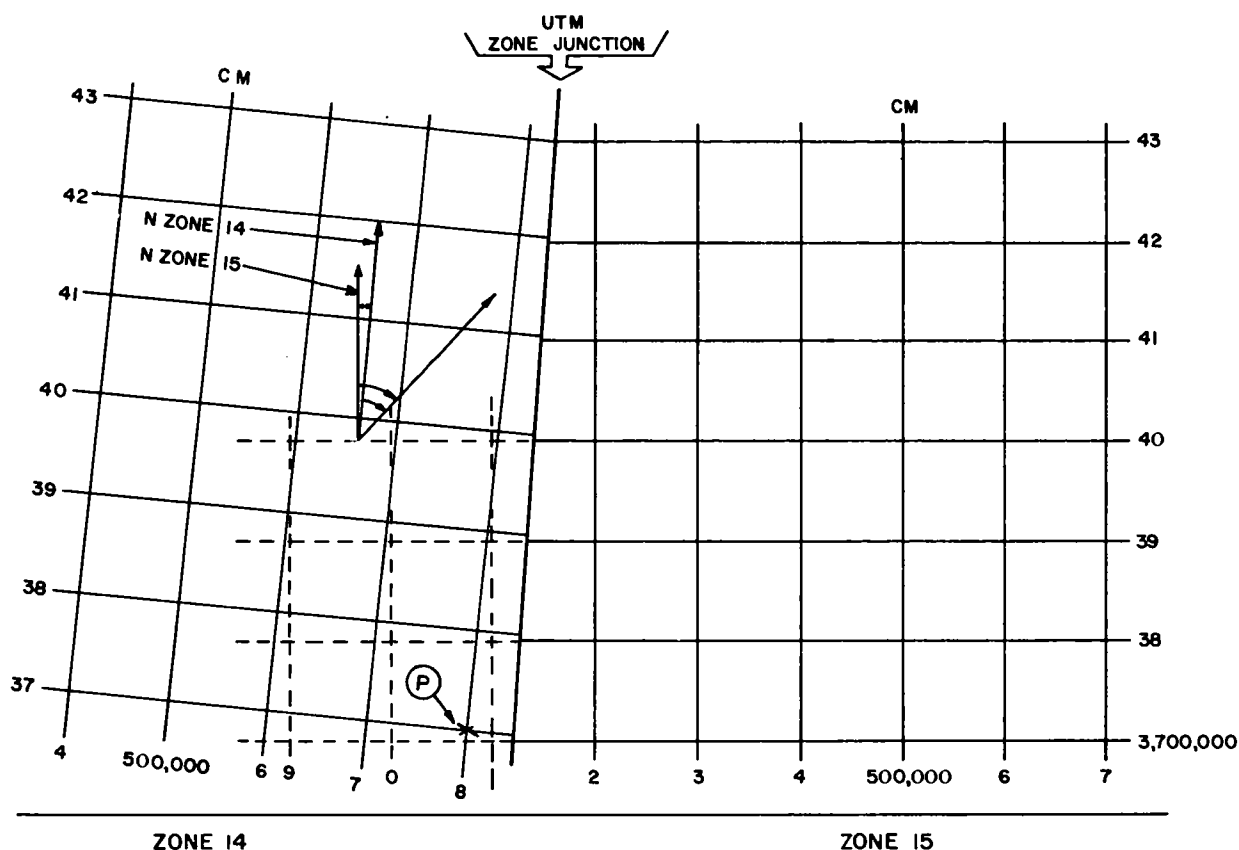


Figure 167. Schematic drawing showing transformation requirements.

- (1) When transforming to the east (such as zone 14 to zone 15), use the e value on the right side of the table and the upper of the signs where there are two shown.
- (2) When transforming to the west (such as zone 15 to zone 14), use the e value on the left side of the table and the lower of the signs.

d. In performing the computations on DA Form 6-36 and considering the initial zone to be A, the resulting E and N coordinates are for the adjacent zone B. In the Southern Hemisphere the transformed northing must be subtracted from 10,000,000 to compute the correct coordinate.

433. Use of DA Form 6-36

a. The use of forms will simplify transformation computations. The form used for zone-

to-zone universal transverse mercator grid coordinates transformation is DA Form 6-36 (fig. 168). This form is designed for use with a computing machine. If a computing machine is not available, multiplication is performed on a separate paper by using logarithms or direct multiplication and the results are entered in the proper spaces. The form is executed in a straight numerical sequence with the values in lines 11 through 18 (N_0 , E_0 , a_1 , a_2 , b_1 , b_2 , c_2 , and c) extracted from TM 5-241-2 for the proper spheroid.

b. Formulas on which the form is based, are shown on the back of the form.

434. Transformation of UTM Grid Azimuth from Zone-to-Zone

The same reasons for transforming grid coordinates (par. 431) are applicable to grid

ZONE TO ZONE UTM GRID COORDINATES TRANSFORMATION											
STATION SILL						LOCALITY FT SILL, OKLAHOMA					
FROM ZONE A 14 TO ZONE B 13						SPHEROID CLARKE 1866					
1 2 3 4 5 6 7 8 9 10 11 12						5 USE ONLY FOR SOUTHERN HEMISPHERE 10 000 000 00					
1 E (Zone A) + 556 139 87						6 N (Zone A) + 3 833 334 09					
2 (1) TO NEAREST 100,000 METERS (e) - 600 000 00						7 (5) - (6) FOR SOUTHERN HEMISPHERE +					
3 ALGEBRAIC SUM (1) AND (2) ⊕ 43 860 13						8 (6) OR (7) TO NEAREST 100,000 METERS = (n) - 3 800 000 00					
4 REPEAT (3) WITH DECIMAL POINT MOVED LEFT FIVE PLACES = e' ⊕ 0 4386013						9 ALGEBRAIC SUM (6) OR (7) AND (8) ⊖ 33 334 09					
Enter AMS Technical Manual No. 50 for proper spheroid using values from lines (2) and (8) as arguments. When transforming to east, use (e) value on right side of table and upper of signs; for transforming to west, use (e) value on left side of table and lower of signs.						10 REPEAT (9) WITH DECIMAL POINT MOVED LEFT FIVE PLACES = n' ⊖ 0 3333409					
						11 N₀ + 3 822 297 707					
						12 E₀ ⊖ 652 499 349					
						13 a₁ + 100 336 277					
						14 a₂ ⊕ 5 958 532					
						15 b₁ - 8 904					
						16 b₂ ⊕ 68 056					
						17 c₁ ⊕ 0 037					
						18 c₂ ⊕ 0 261					
						19 (1S) - 8 904					
20 (10) X (17) ⊕ 0 012						38 (12) ⊖ 652 499 349					
21 ALGEBRAIC SUM (19) AND (20) ⊕ 8 916						39 (10) X (36) ⊕ 1 992 486					
22 (4) X (18) CHANGE SIGN OF RESULT ⊖ 0 114						40 (4) X (32) ⊕ 43 993 263					
23 ALGEBRAIC SUM (21) AND (22) ⊕ 8 802						41 ALGEBRAIC SUM (37), (38), (39), AND (40) ⊖					
24 (16) ⊕ 68 056						42 E (Zone B) + 1 106 513 600					
25 (10) X (18) ⊖ 0 087						43 (11) + 3 822 297 707					
26 (4) X (17) ⊖ 0 016						44 (10) X (32) ⊖ 33 435 272					
27 ALGEBRAIC SUM (24), (25), AND (26) ⊕ 67 953						45 ALGEBRAIC SUM (42) AND (43) ⊖ 3 855 732 979					
28 (13) + 100 336 277						46 (4) X (36) CHANGE SIGN OF RESULT ⊕ 2 621 662					
29 (10) X (23) ⊕ 2 934						47 ALGEBRAIC SUM (44) AND (45) +					
30 ALGEBRAIC SUM (28) AND (29) ⊖ 100 333 343						48 N (Zone B) + 3 853 111 317					
31 (4) X (27) CHANGE SIGN OF RESULT ⊕ 29 804						49 USE ONLY FOR SOUTHERN HEMISPHERE					
32 ALGEBRAIC SUM (30) AND (31) + 100 303 539						50 REPEAT (46)					
33 (14) ⊕ 5 958 532						51 (47) - (48) FOR SOUTHERN HEMISPHERE					
34 (10) X (27) ⊕ 22 652						52 N (Zone B) +					
35 (4) X (23) ⊖ 3 861											
36 ALGEBRAIC SUM (33), (34), AND (35) ⊕ 5 977 323											
COMPUTER SFC J DOE						CHECKER Op1 R ROE				DATE 1 Feb 1961	

DA FORM 6-36
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Figure 168. Completed DA Form 6-36.

azimuths, and the same reference tables, TM 5-241-2, are employed for the extractions of functions. To understand what transpires when transformation of azimuth takes place, refer again to figure 167. On the UTM zone to the left (zone 14), a line of direction has been indicated. The azimuth of this line is represented by a horizontal clockwise angle from the grid north for zone 14. If the azimuth of that line is transformed to the grid of the adjacent zone (zone 15), the line of direction does not change; however, due to a new grid north reference line, the azimuth of the line will increase. From this figure, in transforming azimuth from a west zone to an east zone, the azimuth will increase; conversely, in transforming azimuth from an east zone to a west zone, azimuth will decrease.

435. DA Form 6-34

a. DA Form 6-34 is used for zone-to-zone UTM grid azimuth transformation (fig. 169). This form, which is similar to DA Form 6-36, also was designed for use with a computing machine. The same procedure as used with DA Form 6-36 is used with this form if a computing machine is not available. Also, values for lines 11 through 17 (a_1 , a_2 , b_1 , b_2 , c_1 , and c_2) are extracted directly from TM 5-241-2, using the tables for the proper spheroid.

b. Formulas on which the form is based, are shown on the back of the form.

436. Transformation of Coordinates for Fourth-Order Surveys

For fourth-order surveys, the steps in transforming the coordinates of points after having obtained the transformed coordinates of one point and the azimuth transformation correction are as follows:

a. Compute the azimuth and grid distance between the point which has been transformed and the point which is being transformed, *using for both points the old zone coordinates.*

b. Transform the computed azimuth by algebraically adding the azimuth transformation correction.

c. Transform the computed grid distance by dividing it by the scale factor for the old zone and multiplying it by the scale factor for the new zone.

d. Compute the differences in easting and northing between the transformed point and the point which is being transformed, *using the transformed azimuth (*b* above) and the transformed distance (*c* above).*

e. Apply the differences in easting and northing to the transformed coordinates of the point which has been transformed.

437. Transformation of Coordinates for Fifth-Order Surveys

For fifth-order surveys it is not necessary to transform the grid distance. The grid distance for the old zone can be used to compute the differences in easting and northing.

ZONE TO ZONE UTM GRID AZIMUTH TRANSFORMATION									
STATION SILL					LOCALITY FT SILL, OKLAHOMA				
FROM ZONE A 14 TO ZONE B 13					SPHEROID CLARKE 1866				
1	AZIMUTH TO BE TRANSFORMED FROM ZONE A TO ZONE B = T_1	0							
	42			17				13	
2	E (Zone A) +			556			139		87
3	(2) TO NEAREST 100,000 METERS = (e)	-					600		000 00
4	ALGEBRAIC SUM (2) AND (3) ⊕			43			860		13
5	REPEAT (4) WITH DECIMAL POINT MOVED LEFT FIVE PLACES = e'	⊕		0			4386013		
Enter AMS Technical Manual No. 50 for proper spheroid using values from Lines (3) and (9) as arguments. When transforming to east, use (e) value on right side of table and upper of signs; for transforming to west, use (e) value on left side of table and lower of signs.					6	USE ONLY FOR SOUTHERN HEMISPHERE			10 000 000 00
7	N (Zone A) +			3			833		334 09
8	(6) - (7) FOR SOUTHERN HEMISPHERE +								
9	(7) OR (8) TO NEAREST 100,000 METERS = (n)	-					3		800 000 00
10	ALGEBRAIC SUM (7) OR (8) AND (9) ⊕						33		334 09
11	REPEAT (10) WITH DECIMAL POINT MOVED LEFT FIVE PLACES = n'	⊕		0			3333409		
12	a ₁ +			100			336		277
13	a ₂ ⊕			5			958		532
14	b ₁ -						8		904
15	b ₂ ⊕						68		056
16	c ₁ ⊕						0		037
17	c ₂ ⊕						0		261
18	(14) X 2 -			17			808		
19	(11) X (16) X 3 ⊕			0			039		
20	ALGEBRAIC SUM (18) AND (19) -			17			847		
21	(5) X (17) X 3, CHANGE SIGN OF RESULT ⊕			0			342		
22	ALGEBRAIC SUM (20) AND (21) -			17			505		
23	(15) X 2 ⊕			136			112		
24	(11) X (17) X 3 ⊕			0			261		
25	(5) X (16) X 3 ⊕			0			048		
26	ALGEBRAIC SUM (23), (24), AND (25) ⊕			135			803		
27	(12) +			100			336		277
28	(11) X (22) ⊕			5			835		
29	ALGEBRAIC SUM (27) AND (28) +			100			330		442
30	(5) X (26) CHANGE SIGN OF RESULT ⊕						59		563
31	ALGEBRAIC SUM (29) AND (30) +			100			270		879
32	(13) ⊕						5		958 532
33	(11) X (26) ⊕						45		269
34	(5) X (22) ⊕						7		678
35	ALGEBRAIC SUM (32), (33), AND (34) ⊕						5		996 123
36							10		000 0000
37	LOG (31)						5		001 1710
38	(36) - (37)						4		998 8290
39	LOG (35)						3		777 8703
40	(38) + (39)						8		776 6993
41	ANGLE WHOSE LOG TAN IS (40), USE SIGN OF (35) ⊕			3			25		20
42	(1) +			42			17		13
43	REPEAT (41), CHANGE SIGN FOR SOUTHERN HEMISPHERE ⊕			3			25		20
44	ALGEBRAIC SUM (42) AND (43)								
					AZIMUTH (Zone B)				
				38			51		53
COMPUTER SFC J DOE					CHECKER Cpl R ROE				
					DATE 1 Feb 1961				

DA FORM 6-34
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Figure 169. Completed DA Form 6-34.

APPENDIX I

REFERENCES

1. Miscellaneous Publications

AR 117-5	Military Mapping and Surveying.
AR 220-50	Regiments; General Provisions.
AR 220-60	Battalions—Battle Groups—Squadrons—General Provisions.
AR 220-70	Companies—General Provisions.
AR 320-5	Dictionary of United States Army Terms.
AR 320-50	Authorized Abbreviations and Brevity Codes.
DA Pam 108-1	Index of Army Motion Pictures, Film Strips, Slides, and Phono-Recordings.
DA Pam 310-series	Military Publications Indexes (as applicable).
FM 6-18	Mortar Battery, Airborne Division, Battle Group.
FM 6-20	Field Artillery Tactics and Techniques.
FM 6-21	Division Artillery.
FM 6-40	Field Artillery Cannon Gunnery.
FM 6-120	The Field Artillery Observation Battalion and Batteries.
FM 6-135	Adjustment of Artillery Fire by the Combat Soldier.
FM 21-5	Military Training.
FM 21-6	Techniques of Military Instruction.
FM 21-26	Map Reading.
FM 21-30	Military Symbols.
FM 21-31	Topographic Symbols.
FM 30-5	Combat Intelligence.
FM 44-1	Air Defense Artillery Employment.
FM 44-2	Light Antiaircraft Artillery (Automatic Weapons).
FM 44-4	Medium and Heavy Antiaircraft Artillery.
FM 57-100	The Airborne Division.
TM 5-231	Mapping Functions of the Corps of Engineers.
TM 5-232	Elements of Surveying.
TM 5-234	Topographic Surveying.
TM 5-236	Surveying Tables and Graphs.
TM 5-241	The Universal Grid Systems.
TM 5-241-1	Grids and Grid References.
TM 5-241-2	Universal Transverse Mercator Grid, Zone-to-Zone Transformation Tables.
TM 5-241-3/1	Universal Transverse Mercator Grid Tables for Latitudes 0° — 80°; International Spheroid (meters) Volume I, Transformation of Coordinates from Geographic to Grid.

TM 5-241-3/2	Universal Transverse Mercator Grid Tables for Latitudes 0° — 80°; International Spheroid (meters) Volume II, Transformation of Coordinates from Grid to Geographic.
TM 5-241-4/1	Universal Transverse Mercator Grid Tables for Latitudes 0° — 80°; Clarke 1866 Spheroid (meters) Volume I, Transformation of Coordinates from Geographic to Grid.
TM 5-241-4/2	Universal Transverse Mercator Grid Tables for Latitudes 0° — 80°; Clarke 1866 spheroid (meters) Volume II, Transformation of Coordinates from Grid to Geographic.
TM 5-241-5/1	Universal Transverse Mercator Grid Tables for Latitudes 0° — 80°; Bessel Spheroid (meters) Volume I, Transformation of Coordinates from Geographic to Grid.
TM 5-241-5/2	Universal Transverse Mercator Grid Tables for Latitudes 0° — 80°; Bessel Spheroid (meters) Volume II, Transformation of Coordinates from Grid to Geographic.
TM 5-241-6/1	Universal Transverse Mercator Grid Tables for Latitudes 0° — 80°; Clarke 1880 Spheroid (meters) Volume I, Transformation of coordinates from Geographic to Grid.
TM 5-241-6/2	Universal Transverse Mercator Grid Tables for Latitudes 0° — 80°; Clarke 1880 Spheroid (meters) Volume I, Transformation of Coordinates from Grid to Geographic.
TM 5-241-7	Universal Transverse Mercator Grid Tables for Latitudes 0° — 45°; Everest Spheroid (meters), Transformation of Coordinates from Geographic to Grid and from Grid to Geographic.
TM 5-241-8	Universal Transverse Mercator Grid.
TM 5-241-9	Universal Polar Stereographic Grid Tables for Latitudes 79° 30' — 90°; International Spheroid (meters), Transformation of Coordinates from Geographic to Grid and from Grid to Geographic.
TM 5-6675-200-15	Theodolite: Directional 5.9 In. LG Telescope; Detachable Tribrach, W/Accessories and Tripod (Wild Heerbrugg Model T-16) FSN 6675-542-1683.
TM 5-6675-213-12	Theodolite, Directional, 1 Sec, Graduation 5.9 In. Length Telescope, W/Tripod, Carrying Case and Accessories, Wild Heerbrugg Instruments, Inc., Model T-2, S/N Ranges 5602 through 17897 and 27235 through 30594 (FSN 6675-232-8972) T-2 Model S/N Ranges 50892 through 55124 (FSN 6675-587-3767).
TM 5-9421	Surveying Altimeters, Wallace & Tiernan Models FA-112, FA-113, and FA-181.
TM 6-230	Logarithmic and Mathematical Tables.
TM 6-240	Rule, Slide, Military, Field Artillery, with Case, 10-inch.
TM 6-300-(61)	Army Ephemeris, 1961.
TB ENG 23	Use of the Tellurometer in Military Surveying. Tellurometer Handbook, Tellurometer (PTV) Ltd, Cape Town, South Africa (issued with each unit). Instruction Manual, EM 2171, for Able (Surveying Instrument, Azimuth, Gyro Artillery) Model XCZA System with Modified Electronic Package, Autonetics, North American Aviation, Inc.

2. DA Forms

5-139

6-1

Field Record and Computations-Tellurometer.

Computation—Azimuth and Distance from Coordinates.

6-2	Computation—Coordinates and Height from Azimuth, Distance, and Vertical Angle.
6-2b	Computation—Trigonometric Heights.
6-5	Record—Survey Control Point.
6-7a	Computation, Plane Triangle, Using Three Sides.
6-8	Computation—Plane Triangle Coordinates and Height from One Side, Three Angles and Vertical Angles.
6-10	Computation—Astronomic Azimuth by Hour-Angle Method, Sun.
6-10a	Computation—Astronomic Azimuth by Hour-Angle Method, Star.
6-11	Computation—Astronomic Azimuth by Altitude Method, Sun or Star.
6-18	Computation—Coordinates and Height from Two-Point Resection.
6-19	Computation—Coordinates and Height from Three-Point Resection.
6-20	Computation—Convergence (Astronomic Azimuth to UTM Grid Azimuth).
6-21	Computation and Instructions for Use with Star Identifier.
6-22	Computation—Conversion UTM Grid Coordinates to Geographic Coordinates (Machine).
6-23	Computation—Conversion Geographic Coordinates to UTM Grid Coordinates (Logarithms).
6-25	Computation—Conversion Geographic Coordinates to UTM Grid Coordinates (Machine).
6-26	Observing Record and Preliminary Computation—Altimetric Height.
6-27	Computation—Altimetric Height (Single-Base or Leapfrog Method).
6-34	Zone to Zone UTM Grid Azimuth Transformation.
6-36	Zone to Zone UTM Grid Coordinates.

3. Other U.S. Government Publications

(Available from The Superintendent of Documents, U.S. Government Printing Office, Washington 25, D.C.)

a. *Department of Commerce.*

Coast and Geodetic Survey: Special Publication No. 225, Manual of Reconnaissance for Triangulation.

Special Publication No. 234, Signal Building.

Special Publication No. 237, Manual of Geodetic Triangulation.

b. *Department of the Navy.*

Naval Observatory: American Ephemeris and Nautical Almanac (published annually).

Air Almanac (published annually). Hydrographic Office: H. O. No. 205, Radio Time Signals (Current Series).

APPENDIX II

SURVEY TECHNIQUES

TRAVERSE

Requirement	Fourth order (1:3000)		Fifth order (1:1000)			1:500
	T2 Theodolite 1-second	T2 Theodolite 0.002 mil	Steel tape and T2 Theodolite (1-second)	Steel tape and T16 Theodolite (0.2 mil)	Steel tape and transit (1-minute or 20-second)	Steel tape and M2 aiming circle
Traverse closed	yes	yes	yes	yes	yes	yes
On second known point	preferred	preferred	preferred	preferred	preferred	preferred
On starting point	acceptable	acceptable	acceptable	acceptable	acceptable	acceptable
Traverse adjusted	yes	yes	no	no	no	no
Closing error in position not to exceed	1:3000	1:3000	1:1000	1:1000	1:1000	1:500
Allowable error in azimuth per main scheme angle	5"	0.02 mil	15"	0.1 mil	15"	0.5 mil
Initial circle settings	0°00'30" ± 20"	0.150 (± 0.10 mil).	0°00'30" ± 20"	1.0 mil	NA	NA
Horizontal angles	1 position	1 position	1 position	1 position	1 D/R	2 repetitions
Vertical angles	1 D/R to HI	1 D/R to HI	1 D/R to HI	1 D/R to HI	1 D/R to HI	2 readings
Distance tellurometer)	2 coarse, 4 fine	2 coarse, 4 fine	single taped checked by pacing	single taped checked by pacing	single taped checked by pacing	single taped checked by pacing
Distance (steel tape)	double taped 1:5000	double taped 1:5000.				
Scale factor	yes	yes	no	no	no	no
Log tables	Vega	TM 6-230 (7-place)	Vega	TM 6-230	Vega	TM 6-230
Bearing angles	10"	.01 mil	10"	0.1 mil	10"	0.1 mil
E and N carried to	0.01 m	0.01 m	0.1 m	0.1 m	0.1 m	0.1 m
H carried to	0.1 m	0.1 m	0.1 m	0.1 m	0.1 m	0.1 m
Horizontal and vertical angles recorded to	1"	0.001 mil	1"	0.1 mil	1"	0.1 mil
Vertical angles used to nearest	10"	0.01 mil	10"	0.1 mil	30"	0.1 mil
Azimuth carried to	1"	0.001 mil	1"	0.1 mil	1"	0.1 mil

TRIANGULATION—INTERSECTION—RESECTION

Requirement	Fourth order (1:3000)		Fifth order (1:1000)		1:500	
	T2 Theodolite 1-second (T2)	T2 Theodolite 0.002 mil (T2)	Steel tape and T2 Theodolite (1-sec)	Steel tape and T16 Theodolite (0.2 mil)	Steel tape and transit (1 min and 20 sec)	Steel tape and M2 aiming circle
Closed (tied to existing control)	yes	yes	yes	yes	yes	yes
Adjusted	yes	yes	no	no	no	no
Closing error in position not to exceed	1:3000	1:3000	1:1000	1:1000	1:1000	1:500
Allowable error in azimuth per main scheme angle	5"	0.02 mil	15"	0.1 mil	15"	0.5 mil
Initial circle settings	0°00'30" ± 20" 270°00'30" ± 20"	0.150 (± 0.10 mil) 4800.150 (± 0.10 mil)	0°00'30" ± 20"	1.0 mil	NA	NA
Horizontal angles	2 positions	2 positions	1 position	1 position	1 D/R	2 repetitions
Vertical angles	1 D/R to HI	1 D/R to HI	1 D/R to HI	1 D/R to HI	1 D/R to HI	2 readings to HI
Distances	double tape to 1:7000 or with tellu- rometer.	double tape to 1:7000 or with tellu- rometer.	double taped 1:3000	double taped 1:3000	double taped 1:3000	double taped 1:3000
Scale factor	yes	yes	no	no	no	no
Log tables	Vega	TM 6-230 (7 place)	Vega	TM 6-230	Vega	TM 6-230
Bearing angles	1"	0.01 mil	1"	0.1 mil	1"	0.1 mil
E and N carried to	0.01 m	0.01 m	0.1 m	0.1 m	0.1 m	0.1 m
H carried to	0.1 m	0.1 m	0.1 m	0.1 m	0.1 m	0.1 m
Horizontal and vertical angles recorded to	1"	0.001 mil	1"	0.1 mil	1"	0.1 mil
Vertical angles used to nearest	1"	0.01 mil	1"	0.1 mil	30"	0.1 mil
Azimuth carried to	1"	0.001 mil	1"	0.1 mil	1"	0.1 mil
Minimum distance angles	22½° pref 30°	400 mils pref 533 mils	22½° pref 30°	400 mils pref 533 mils	22½° pref 30°	400 mils pref 533 mils
Minimum apex angle tgt area inter- section	NA	NA	NA	150 mils	NA	150 mils
Triangle closure.	Average for scheme 12", max for tri- angle 15"	Average for scheme 0.05 mil max for triangle 0.06 mil	± 30"	± 0.3 mils	± 30"	± 1.0 mil

ASTRONOMIC OBSERVATIONS

Requirement	Fourth order			Fifth order		
	1-second Theodolite (T2)	0.002 mil Theodolite (T2)	1-second Theodolite (T2)	0.2 mil Theodolite (T16)	1-min or 20-sec transit	Aiming circle* (M2)
Minimum number of sets to be observed.	3	3	3	3	3	4
Rejection limit.	30"	0.15 mil	60"	0.3 mil	60"	0.3 mil
Number of sets that must remain and be remeasured.	2	2	2	2	2	3
Horizontal angles.	1 position	1 position	1 position	1 position	1 D/R	2 readings
Vertical angles.	1 D/R	1 D/R	1 D/R	1 D/R	1 D/R	2 readings
Considered accuracy.	30"	0.15 mil	60"	0.3 mil	60"	0.3 mil

*Specifications apply for determining a fifth-order azimuth. If the direction is not to be extended from the line established by the observation, the rejection limit can be relaxed to 1.0 mil with a considered accuracy of 1.0 mil.

APPENDIX III

DUTIES OF SURVEY PERSONNEL

1. Survey Officer

The survey officer—

- a. Coordinates and supervises training of survey personnel.
- b. Coordinates, supervises, and *emphasizes* the preventive maintenance program on survey equipment.
- c. Coordinates, supervises, and establishes the survey information center (when the SIC is authorized at his echelon).
- d. Accompanies the commander on reconnaissance.
- e. Formulates and implements the survey plans.
- f. Supervises and coordinates the field operation of survey parties under his jurisdiction.
- g. Advises the commander and staff on survey matters.
- h. Coordinates survey operations with survey officers of higher, lower, and adjacent headquarters.

2. Chief Surveyor (Surveyor)

The chief surveyor (surveyor)—

- a. Acts as principal assistant to the survey officer and when directed performs any or all of the duties of the survey officer.
- b. Supervises survey personnel in performance of routine reconnaissance, communications, and survey activities.
- c. Performs other duties as directed.

3. Chief of Survey Party

The chief of survey party—

- a. Trains the survey party for which he is the chief.
- b. Implements his party's portion of the survey plan.

- c. Orients party members on the survey plan.
- d. Supervises and coordinates the field operation of his survey party.
- e. Maintains liaison with the survey officer or chief surveyor during field operations.
- f. Supervises preventive maintenance on section equipment, to include vehicles and communications equipment.
- g. Performs other duties as directed.

4. Chief Survey Computer

The chief survey computer—

- a. Acts as principal assistant to chief of survey party and is capable of performing the duties of the chief of survey party.
- b. Maintains a stock of all required DA forms for computation of surveys.
- c. Supervises and assists in training members of the survey party to perform survey computations.
- d. Performs survey computations independently during field operations.
- e. Actively supervises the other survey computer during field operations.
- f. Insures that all computations are checked for accuracy.
- g. Performs other duties as directed.

5. Survey Computer

The survey computer—

- a. Assists the chief survey computer in the maintenance of required DA forms for computation of surveys.
- b. Performs computations independently during field operations.
- c. Performs other duties as directed.

6. Instrument Operator

The instrument operator—

- a.* Performs preventive maintenance on the authorized instruments.
- b.* Operates the instrument during field operations.
- c.* Verifies vertical alinement of the range pole before measuring angles during field operations.
- d.* Reads measured values to the recorder and checks the recorder's operation by use of a read-back technique.
- e.* Familiarizes himself with fieldwork requirements for all survey methods.
- f.* Assists tapeman in maintaining alinement during taping operations.
- g.* Performs other duties as directed.

7. Recorder

The recorder—

- a.* Maintains an approved notebook (level, transit, and general survey record book, DA Form 6-72, or book transit, or field book) record of all surveys performed by the survey party.
- b.* Records survey starting data and all measured data with a 4-H pencil in a neat and legible manner during field operations.
- c.* Sketches, in the approved notebook, complete descriptions of principal stations occupied during field survey operations.
- d.* Checks, means, and adjusts angular data measured by the instrument operator.

- e.* Checks taped distances by pacing.

f. Provides required field data to the chief survey computer and survey computer independently.

- g.* Performs other duties as directed.

8. Tapeman

The tapeman—

- a.* Maintains the fire control set, artillery survey third (fourth) order.
- b.* Tapes distances using proper taping techniques during field operations.
- c.* Computes an accuracy ratio for taped distance when required.
- d.* Reports measured distances to the recorder.
- e.* Operates and maintains section radio equipment.
- f.* Performs other duties as directed.

Note. Rear tapeman commands the taping team.

9. Rodman

The rodman—

- a.* Maintains station marking equipment.
- b.* Marks stations with hub and witness stake during field operations.
- c.* Centers and plumbs survey range poles over survey stations as required during field operations.
- d.* Assists the tapeman in maintaining alinement of the tape.
- e.* Operates and maintains section radio equipment.
- f.* Performs other duties as directed.

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WORLD STAR CHART

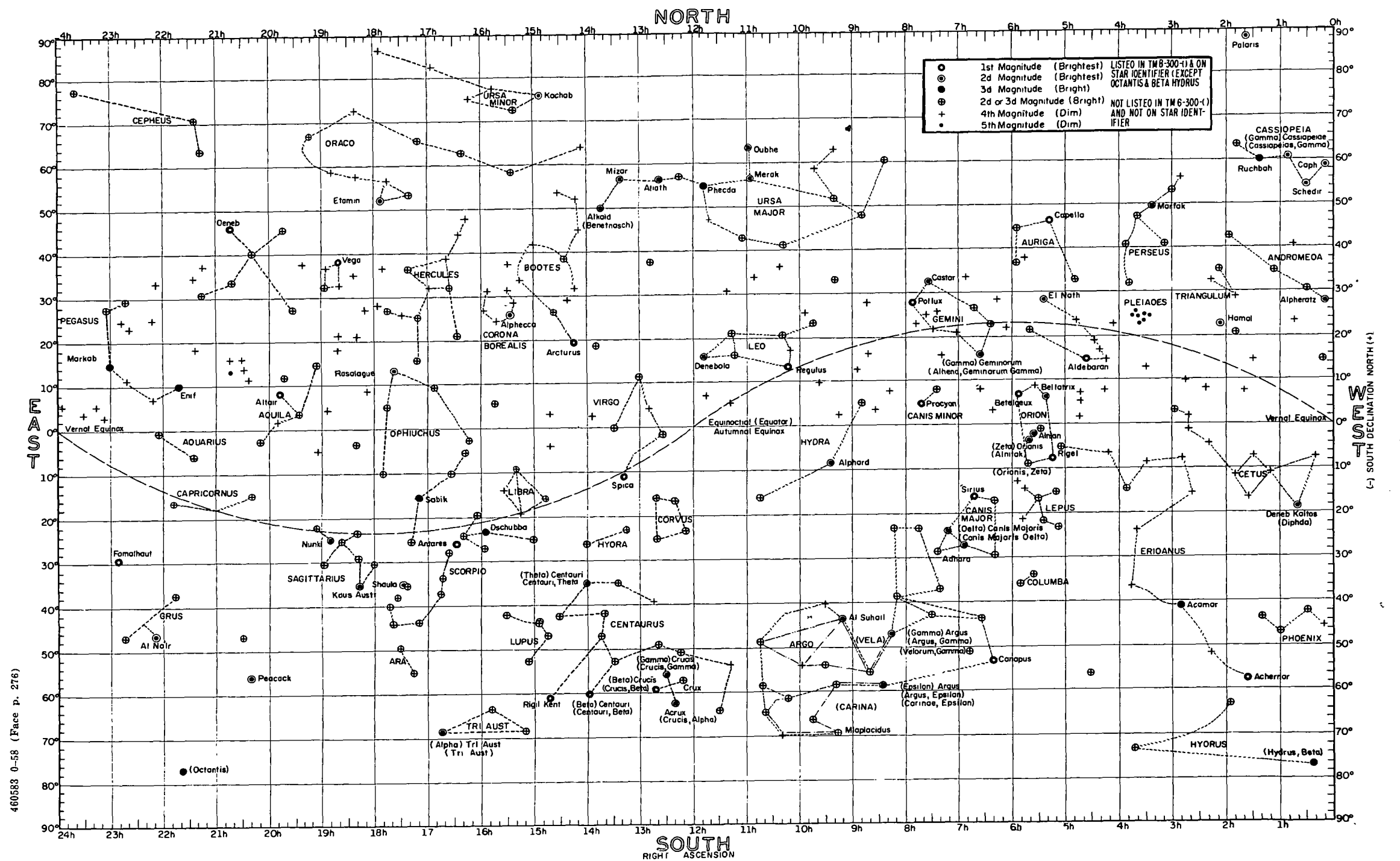


Figure 141. World star chart.

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